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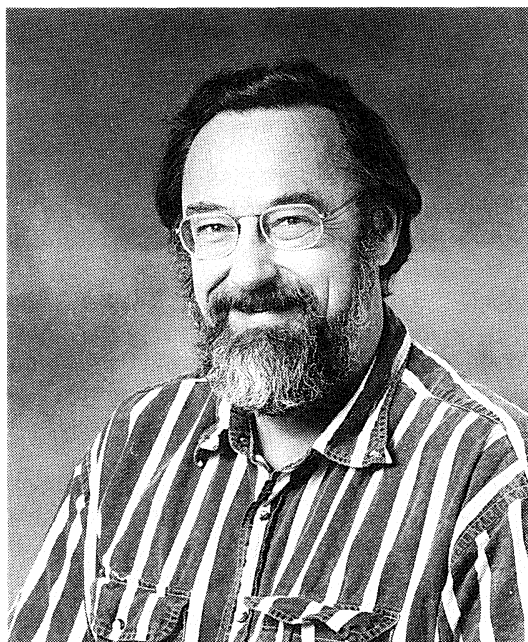
Cryptozoology at the fuzzy edge of ocean discovery

Paul H. LEBLOND*

Curiosity is the mainspring of science. The urge to discover and to explain is truly irrepressible. It cannot be satisfied by dogmatic explanations, nor will it be constrained within the narrow disciplines of organized science. Anyone can be curious about anything; it is not rare to find physicists or chemists fascinated by biological questions, or biologists attracted by geological problems. Sometimes these wanderings lead to a major career reorientation; sometimes they remain a part-time amusement, an enriching hobby. So it is with my interest in cryptozoology.

Cryptozoology is the study of animals whose existence remains doubtful because of insufficient material evidence. It is a field which attracts very wide interest. Rumours about a serpentine animal in Loch Ness, or a giant snow ape in the Himalayas, to mention the best known cryptids (hidden animals) have intrigued everyone for decades. It is unfortunately also a field reputed for hoaxes, gullibility and lack of scientific rigour. Most scientists will not waste their time not risk tarnishing their reputation by publicly succumbing to cryptozoological curiosity.

I certainly used to be one of those who laughed at the idea of sea-serpents... dreams of drunken sailors, I thought. My un-informed skepticism was however severely shaken when I read Bernard HEUVELMANS' (1968) serious and meticulously documented tome on the subject. There had clearly been many observations, by reliable and reputable witnesses, over the past centuries, which could not by any means be explained in terms of known marine animals. Some of these had even occurred in coastal wa-



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ters near my home in western Canada. It was tempting to believe that HEUVELMANS, working from Europe, might have missed some local reports and I decided to investigate further. This led me to discover a rich folklore and much earlier work on *Cadborosaurus* (more familiarly known as *Caddy*), the large serpentine cryptid spotted by many observers in coastal waters of the eastern Pacific, and to associate with other, similarly minded, scientists and amateurs attracted to the mysteries of the sea. I have had no reason to regret the youthful impulse which suggested this eccentric interest. My professional life has been broadened beyond the bounds of physical oceanography, which has however remained my primary discipline and the basis for the scientific rigour which I have tried to apply to cryptozoology.

It would be absurd for a marine scientist,

* Department of Earth and Ocean Sciences, University of British Columbia, Vancouver. B.C. Canada V6T 1Z4

who devotes his career to exploring the sea, to claim *a priori* that there is nothing new to discover in the oceans. Many marine creatures easily avoid our nets and only a small portion of the deep ocean has been visually inspected. Human exploration has thrown a mere flicker of light in a vast hidden darkness. We have quickly become used to the presence of giant clams and tube-worms living near deep hot vents on spreading ridges, but recent discoveries of other chemotrophic communities near cold seeps in the Gulf of Mexico and the Mediterranean (CORSELLI *et al.*, 1996) or over methane vents off the Oregon margin (WHITICAR *et al.*, 1994) have expanded even further the range of habitats and life forms to be expected in the ocean. New species of pelagic octopus, filmed from submersibles, remain at large (LUTZ and VOIGHT, 1994). Unexpected species of fish, like the coelacanth, or the megamouth shark (TAYLOR *et al.*, 1983), keep turning up. What else might the sea hide? Might there not be some real animal behind these hundreds of observations of sea-serpents?

Previous findings do not of themselves imply future discoveries. To claim that the accidental discovery of the coelacanth must necessarily lead to other similar discoveries is completely absurd. Evidence, rather than expectations must guide interpretation. Those same rules which apply to the interpretation of data in other areas of science should apply to cryptozoology. Being willing to accept that there may still exist undiscovered animals in the sea does not mean that every unexplained shadow counts as evidence of their presence. In many cases, as I quickly realized, it is impossible to be sure and one must remain in doubt, cumulating a growing body of observations which never quite add up to the certainty of a specimen in hand.

Cryptozoology operates within that realm of cognition which lies between suspicion and certainty. Scientific discovery normally takes place over an interval of time, starting with glimpses, un-explained observations, syntheses, insights and explanations culminating into consensual certainty. A new animal may be discovered by science through eye-witness reports, fragments of anatomy, photographs, and

eventually a carcass or a live specimen. There are numerous classic examples (the giant squid, the gorilla, the okapi, the platypus) where initial skepticism gradually led to acceptance as evidence accumulated. A recent example is that of the new bovids recently discovered in Vietnamese forests (Vu Van DONG *et al.*, 1993).

Of course, it is only the success stories which eventually enter the zoology textbooks. Unconfirmed rumours remain within the nebulous realm of cryptozoology. In order to enhance the probability of eventual success and avoid misleading reports, rules of evidence have to be introduced. There are too many cases where witnesses have clearly been carried away by their imagination or have been misled by waves, floating objects and already known animals which they failed to recognize.

Two simple rules have been my guide in sifting eye-witness reports of Caddy and other cryptids. First, to be worth attention as a cryptid sighting, an observation must unambiguously pertain to an animal: not to waves, branches, algae or other natural or artificial objects. If there is any doubt in the eyes of the witnesses, or of immediate commentators, the observation is rejected. This first criterion eliminates a large number of unexplained surface phenomena not directly associated with an animal. In particular, it eliminates all those wakes or shadows which have been attributed to a putative animal hidden below the surface, unseen by observers.

The second rule states that the animal observed must clearly not be one which is already known to science. Again, if there is any doubt in the minds of the witnesses, or if their description of the animal which they saw is clearly reminiscent of an animal known to others, if not to the observers themselves, the observation is rejected. In many cases, possible sightings of *Cadborosaurus* have been excluded because of possible confusion with sea-lions.

Strict observation of the above rules may lead to dismissal of some valid sightings. For example, many of the observations made in Loch Ness consist of unexplained surface wakes, which would not satisfy the above

criteria. An unexplained surface phenomenon need not always have been caused by an animal. The quality of cryptozoological evidence is so often debatable that every effort must be made to exclude doubtful reports right from the beginning. The application of these strict rules still leaves us with a solid body of cryptozoological evidence. HEUVELMANS (1968), and more recently BRIGHT (1989) and ELLIS (1994) have reviewed world-wide reports of marine cryptids.

Observations which I have collected and analyzed off the west coast of Canada have been published in LEBLOND and BOUSFIELD (1995). Our conclusion is that there appears to exist a large deep-water animal, a serpentine, fish-feeding, air breathing, long-necked creature with a mixture of reptilian and mammalian characteristics and puzzling habits. This is the animal referred to as *Cadborosaurus*. Only an actual specimen, dead or alive will provide definitive proof of Caddy's existence. Cryptozoological interest may help in finding that specimen and recognizing it when it is at hand.

Laboratory analyses may also be helpful when there is some parcel of material evidence at hand. The piece of blubber preserved from the mysterious giant blob discovered near St. Augustine in 1896 has already been subjected to analyses which have helped in determining its nature (VERRILL, 1897; WOOD and GENNARO, 1991; MANGIACOPRA *et al.*, 1994; PIERCE *et al.*, 1995). Similarly, a piece of the carcass collected by a crew member of the *Zuiyo Maru* off New Zealand in 1977 could be used to perform an immunological analysis which suggested that the animal was indeed a shark (SASAKI, 1978). In the absence of material remains, other analyses may be used, most particularly in the interpretation of photographs. Using simple results about wind waves, I tried to estimate the size of the Loch Ness cryptid from the length of the waves visible in the famous "Surgeon's photograph" (LEBLOND and COLLINS, 1987). Unfortunately, it has since been revealed that this photograph was a hoax and that the actual object was smaller than what we calculated (BOYD and MARTIN, 1994).

Another issue of interest to oceanographers, and indeed to all scientists, is that of

recognition of significant information in noisy data. Physical oceanographers commonly extract signals from images or time series by using filters or spectral methods. These methods also apply to the interpretation of alleged cryptid images. I have had interesting arguments with Nessie and other cryptid enthusiasts attempting to find significance in the grain pattern of enlarged photographs. As in all observations, one must not read more information than is contained in the data.

In a more philosophical vein, cryptozoology brings one face-to-face with the problem of incorporating new knowledge within the body of science. How much information is necessary for new facts to be accepted? Are unconfirmed reports to be entirely dismissed until the day when material proof becomes available, at which point full acceptance is granted? What is the curious seeker to do during the intervening period, while searching for more solid evidence? Speculate, of course. Formulate theories, for discussion and guidance. Astrophysical journals, for example, are replete with logical speculations, based on physics and chemistry, and framed in the language of mathematics, about unexplained cosmic phenomena. These speculations guide and stimulate further observations. Similarly, cryptozoological publications speculate, as logically as possible, and within the laws of science, about how to interpret poorly observed animals. The observations are usually based on eye-witness reports and are thus "fuzzy" in the sense that they are stated in words and in subjectively produced drawings rather than in objective measurements. One sometimes refers to activities which cut away the veil of doubt as being at the "cutting" edge of science. Because cryptozoology deals with fuzzy data, it never quite eliminates all doubt and remains at a "fuzzy" edge of discovery. As soon as proof is achieved, for example through capture of a specimen, zoology replaces cryptozoology and the search is over.

Finally, given the intense public interest in mysterious creatures, I have found cryptozoology to be an excellent way to introduce marine science to people who might not otherwise be interested or might be daunted by a

more traditional approach... a bit like teaching paleontology to children through their interest in dinosaurs. As a teacher, I have found cryptozoology a useful pedagogical support.

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Effects of cobalt and vitamin B₁₂ additions on the growth of two phytoplankton species

Ana Z. SEGATTO*, Edna GRANÉLI* and Conny HARALDSSON**

Abstract: The effect of cobalt on the growth rate/biomass accumulation of a diatom, *Ditylum brightwellii* Bailey and a dinoflagellate, *Prorocentrum minimum* (Pavillard) Schiller was investigated. Experiments were performed under laboratory conditions in polycarbonate flasks with diluted (26 ‰), sterilized, and nutrient enriched sub-surface Atlantic water as growth media. Cobalt was added in concentrations between 0.5 and 3 nM, which corresponds to Co concentrations found in oligotrophic oceans and coastal waters of the Kattegat and the Skagerrak. Cell densities and chlorophyll *a* concentrations were monitored daily during the course of the experiment. *P. minimum* growth rate and biomass accumulation were not affected by cobalt additions, while *D. brightwellii* had both its growth rate and biomass accumulation inhibited by cobalt additions.

1. Introduction

As essential cofactors in metalloenzymes trace metals can influence the metabolism of algal cells (SUNDA, 1988-1989). Different phytoplankton species have different requirements for, and sensitivities to, trace metals (BRAND *et al.*, 1983; BRAND, 1991). Laboratory studies (SUNDA *et al.*, 1981; RUETER and MOREL, 1981) and field studies (MARTIN *et al.*, 1989; MARTIN and GORDON, 1988) have indicated that trace metals may affect not only algal growth but also the primary production, species composition and the trophic structure of phytoplankton communities.

Cobalt is one of the most important limiting trace metals for algal growth, since it is needed for the synthesis of vitamin B₁₂. It has been suggested that the synthesis of this vitamin can be limited by the amount of cobalt in the environment (SANGFORS, 1988; SWIFT, 1980).

Cobalt can stimulate nitrogen fixation and growth rates of blue-green algae (HOLM-HANSEN *et al.*, 1954; SAUBERT and STRIJDOM, 1968). Recently it has been found that cobalt and cadmium can substitute for zinc, another limiting

trace element, promoting the growth of the diatom *Thalassiosira weissflogii* (PRICE and MOREL, 1990). GRANÉLI and RISINGER (1994) have recently shown that cobalt (as cobaltacetate or vitamin B₁₂) favours the biomass accumulation of the toxic flagellate *C. polylepis*.

The aim of this experimental study was to test the effect of different additions of cobalt and vitamin B₁₂ on two coastal phytoplankton species: the diatom *Ditylum brightwellii* and the dinoflagellate *Prorocentrum minimum*.

2. Material and methods

The experiments were performed at laboratory conditions (temperature of 15°C; 16:8 hours light : dark cycle) with monocultures of the dinoflagellate *P. minimum* and of the diatom *D. brightwellii*.

Light intensity was measured with a QSL-100 spherical quantummeter (Biospherical Instruments Inc.) and was approximately 120 $\mu\text{E m}^{-2} \text{s}^{-1}$ (Philips cool-white fluorescent tubes) for the diatom and 90 $\mu\text{E m}^{-2} \text{s}^{-1}$ for the dinoflagellate.

Surface water ($\approx 35.0 \text{ ‰}$) was collected in the Northern Atlantic (61° 11' 14" N - 45° 00' W), and contained low cobalt concentration ($\approx 0.02 \text{ nM}$). In the laboratory the water was prefiltered through a GF/C filter and diluted to 26.0

* Department of Marine Ecology, Ecology Building, University of Lund, 223 62, Lund, Sweden

** Department of Analytical and Marine Chemistry, University of Gothenburg, 412 96, Gothenburg, Sweden

‰ with ultraclean water (obtained from a Milli-Q purification system) in order to maintain the same salinity as that at which these algae had been kept in cultures. The initial concentrations of dissolved inorganic nutrients in the Atlantic water were $0.11 \mu\text{M}$ of nitrate; $0.1 \mu\text{M}$ of phosphate; $0.28 \mu\text{M}$ of ammonia and $2.74 \mu\text{M}$ of silicate. After autoclaving in 20 l Teflon bottles, the water was transferred to 1 l polycarbonate flasks, which had been pretreated for one week with a 1 : 1 mixture of 1.0 M HCl and 1.0 M HNO_3 (Merck, Suprapure), followed by two weeks soaking in a weaker acid mixture.

D. brightwellii and *P. minimum* were first cultured in full f/2 medium (GUILLARD and RYTHYER, 1962), including cobalt (at concentrations of 5×10^{-8} M). Nutrient stock solutions were pretreated in a chelating ion exchange resin (Chelex 100) column in order to eliminate possible contaminations by metals (MOREL *et al.*, 1979; PRICE *et al.*, 1988–1989). During the exponential phase of growth, we made sequential transfers of algae to a cobalt-free medium and phosphorus ($0.5 \mu\text{M}$ as Na_2HPO_4), and nitrogen ($5 \mu\text{M}$ as NaNO_3) were added to all bottles while silicon ($5 \mu\text{M}$ as $\text{Na}_2\text{SiO}_3 \cdot 5\text{H}_2\text{O}$) was added only to the diatom *D. brightwellii* cultures.

Different cobalt treatments were tested : additions of cobalt (as cobaltacetate, $(\text{CH}_3\text{COO})_2\text{Co} \cdot 4\text{H}_2\text{O}$) alone or together with 500 nM of the chelator EDTA (added as the disodium salt) and vitamin B_{12} (as $\text{C}_{63}\text{H}_{88}\text{CoN}_{14}\text{O}_{15}\text{P}$), both in the range 0.5 to 3.0 nM. The different added vitamin B_{12} concentrations were calculated in order to have the same amount of inorganic cobalt added as for the treatment with cobaltacetate. Four replicates were made for each treatment, making a total of 64 bottles. The reason to choose this range of cobalt concentrations was that we would like to compare our results with the results found by GRANÉLI and RISINGER (1994) on the effects of cobalt on the toxic blooming flagellate *C. polylepis*.

Phytoplankton biomass in bottles was estimated as *in vivo* chlorophyll fluorescence using a Turner 112 filter fluorometer and transformed to absolute chlorophyll *a* values (as $\mu\text{g l}^{-1}$) after spectrophotometric analysis of

extracted chlorophyll *a* (according to JEFFREY and HUMPHREY, 1975) during certain days of the experiment. Daily phytoplankton samples were preserved with acidified Lugol's solution and cell counting was performed using Palmer Maloney Chambers in an inverted Nikon TMD Diaphot microscope.

Growth rates based on cell densities were calculated for every bottle during the exponential phase of growth. Growth rates (div. day^{-1}) were calculated according to the formula: $\text{div. day}^{-1} = (\log_2 N - \log_2 N_0) / t$, where N_0 = cell numbers on Day 3; N = cell numbers on Day 9 and $t = 7$ days.

Samples for cobalt analyses in the growth media were collected at the beginning of the experiment (Days 1 and 4 for the dinoflagellate and the diatom, respectively); during the exponential growth phase (Days 11 and 16 for the dinoflagellate and Days 6 and 8 for the diatom) and at the end of the experiments (Days 48 and 17 for the dinoflagellate and the diatom, respectively). One hundred ml of water was then filtered ($0.45 \mu\text{m}$ acid-washed Whatmann GF/C filter) through an acid-cleaned filtration system, in a laminar-flow sterile bench in order to avoid bacterial and/or metal contamination. Measurements of the total dissolved cobalt concentrations in the medium were carried out using the method of DANIELSSON *et al.* (1982). The method consists of complexing the total amount of cobalt present in the sample with a complex agent, such as carbamate. Afterwards the Co-dithiocarbamate complexes are then extracted with an organic solvent (Freon-TF) and finally back-extracted, i.e. extracted from the organic solvent with nitric acid, to an aqueous solution. The total amount of Co present in the solution is then measured.

3. Results

Cobalt concentrations in the initial medium and during the exponential growth phase for the treatments with additions of Co (as cobaltacetate) are shown in Table 1. The results indicate that there was an uptake of cobalt by *D. brightwellii* during the exponential growth phase (on Days 6 and 8 for the control and the treatments with 0.5 and 3.0 nM of added Co) and by *P. minimum* (on Days 11 and

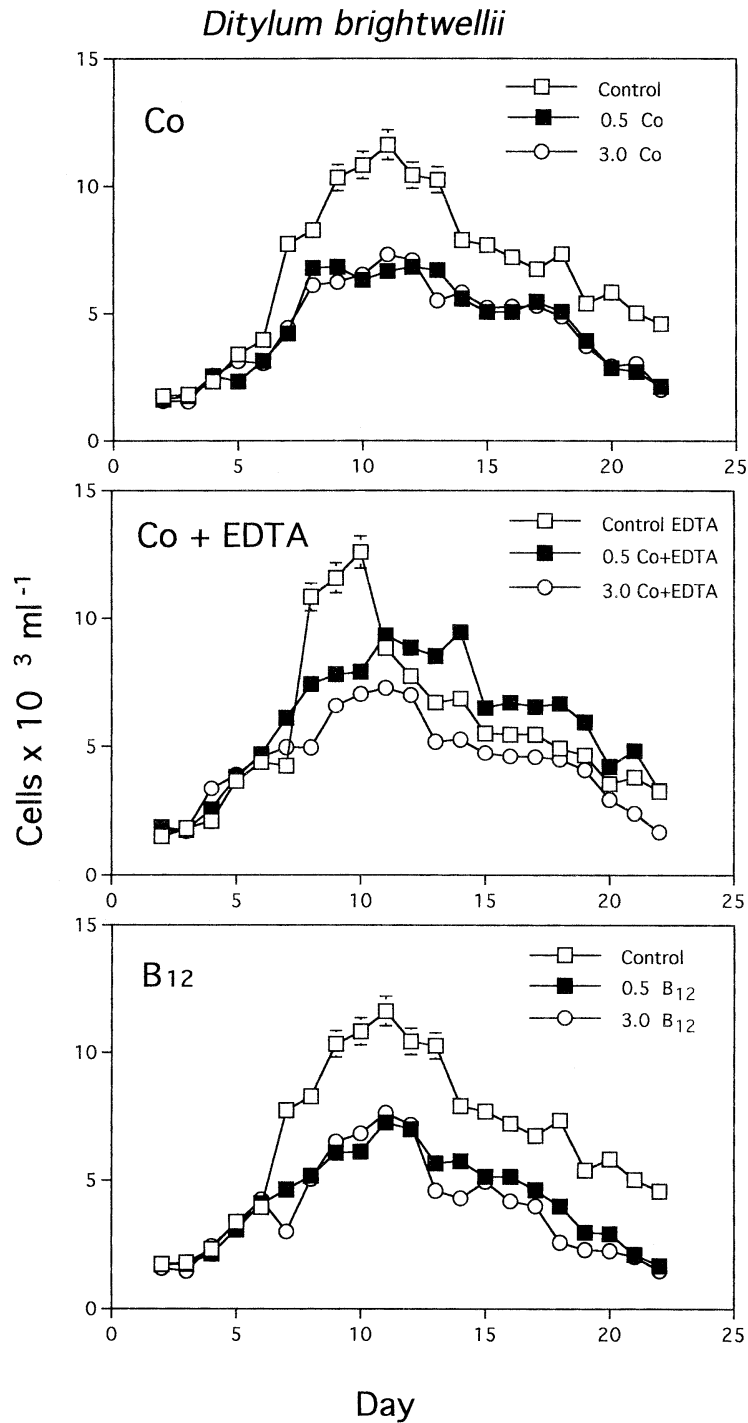


Fig. 1. Effects of different cobalt additions (as Co; Co+EDTA and vitamin B₁₂) on the cell densities of *Ditylum brightwellii*. Control: no Co or vitamin B₁₂ additions.

Table 1. Specific growth rates (doublings per day, μ) from day 3 to day 9.

Values are mean of 4 replicates \pm standard deviation.

The Mean-Whitney U test was used in order to compare the growth rates in the controls with the different treatments.

Treatment	<i>D. brightwellii</i>	<i>P. minimum</i>
Control	0.25 \pm 0.05	0.15 \pm 0.00
0.5 nM Co	0.19 \pm 0.01*	0.20 \pm 0.01*
3.0 nM Co	0.18 \pm 0.03*	0.19 \pm 0.01*
Con+EDTA	0.24 \pm 0.02	0.18 \pm 0.02
0.5 Co+EDTA	0.20 \pm 0.02	0.19 \pm 0.00
3.0 Co+EDTA	0.17 \pm 0.01*	0.22 \pm 0.02*
Control B12	0.25 \pm 0.05	0.16 \pm 0.01
0.5 nM B12	0.17 \pm 0.00*	0.19 \pm 0.02
3.0 nM B12	0.19 \pm 0.02*	0.20 \pm 0.01*

* $p < 0.05$

16 for treatments with 3.0 nM Co additions and in the control flasks).

The growth response of the two phytoplankton species to cobalt additions were different. Maximal cell numbers of the diatom *D. brightwellii* (Fig. 1) were reached for the controls (no Co or B₁₂ added) of cobalt and vitamin B₁₂ additions, and also the controls with additions of only EDTA. There was a significant ($p < 0.05$, Mann-Whitney U-test) increase of cells in the control treatments of *D. brightwellii* compared with the treatments with 0.5 and 3.0 nM of added cobalt (as cobaltacetate or as vitamin B₁₂). *D. brightwellii* reached the maximal biomass accumulation (12 $\mu\text{g l}^{-1}$ of chlorophyll *a*) during the stationary growth phase, for the controls of Co and vitamin B₁₂ additions. For the other treatments, maximal chlorophyll *a* values were less than 9 $\mu\text{g l}^{-1}$. Maximal chlorophyll *a* concentrations were significantly higher in the controls than in the treatments with additions of 0.5 and 3 nM of Co (Fig. 2; $p < 0.05$, Mann-Whitney U-test). The chlorophyll accumulation of the diatom in the treatment with additions of 0.5 and 3.0 nM of cobalt together with EDTA was significantly higher compared with additions of 0.5 and 3.0 nM of cobalt alone (as a salt or as vitamin B₁₂).

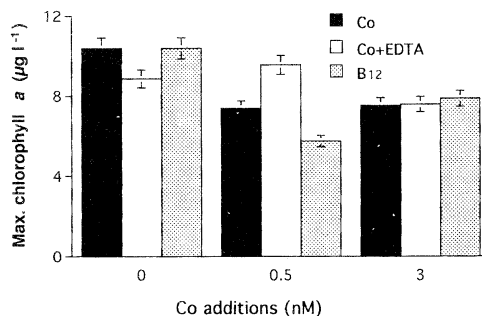


Fig. 2. Maximal biomass accumulation (expressed as chlorophyll *a* concentrations) of *Ditylum brightwellii* grown at different additions of Co, Co+EDTA and vitamin B₁₂. The initial chlorophyll *a* concentration just after the inoculation (Day 1) was 2 $\mu\text{g l}^{-1}$.

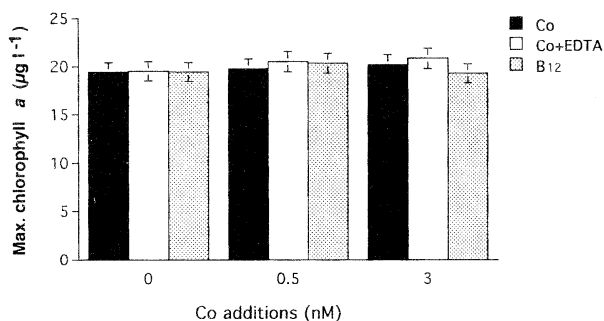


Fig. 4. Maximal biomass accumulation (expressed as chlorophyll *a* concentrations) of *Prochlorocentrum minimum* grown at different additions of Co, Co+EDTA and vitamin B₁₂. The initial chlorophyll *a* concentration just after the inoculation (Day 1) was 4 $\mu\text{g l}^{-1}$.

For *P. minimum* (Fig. 3) the effect of adding Co as a salt, with EDTA or as vitamin B₁₂ were similar. There was a lag phase of approximately 6 days, whereafter exponential growth started. Maximal cell densities were reached after approximately 16 days. The dinoflagellate was maintained for a long time in the stationary growth phase (almost 30 days), and maximal cell densities reached approximately 20×10^3 cells ml^{-1} . No significant differences in cell numbers were observed between the different treatments ($p < 0.05$, Mann-Whitney U-test). Just after the stationary phase, cell numbers of the dinoflagellate were significantly higher in the treatments with Co+EDTA additions compared with the treatments to which we have added Co (as cobaltacetate or as vitamin B₁₂). The maximal chlorophyll *a* accumulation (20

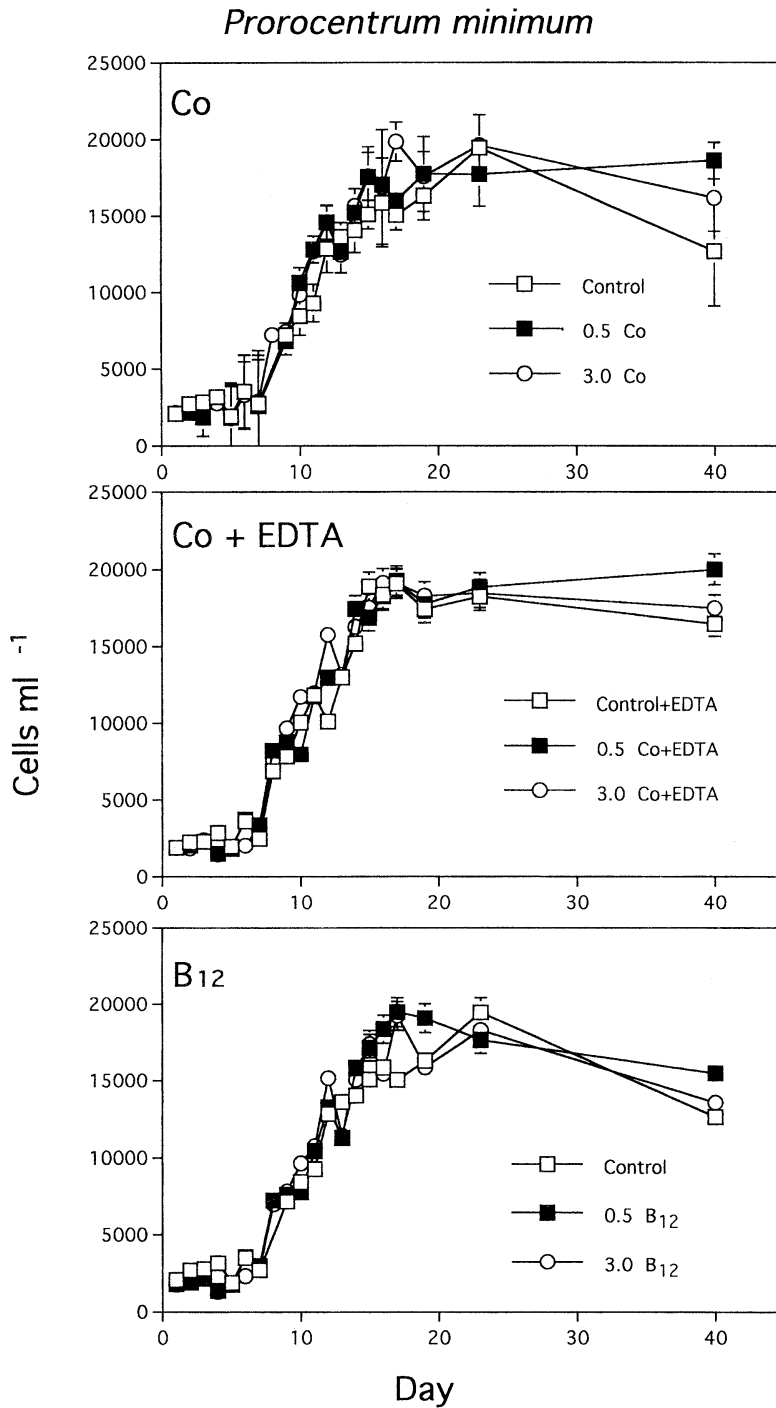


Fig. 3. Effects of different cobalt additions (as Co; Co+EDTA and vitamin B₁₂) on the cell densities of *Prorocentrum minimum*. Control: no Co or B₁₂ additions.

Table 2. Cobalt concentrations (in nM) in the medium for the treatment with no Co additions (Control) and cobalt added at concentrations of 0.5 and 3.0 nM. The initial concentration of Co in Atlantic water was 0.02 nM.

Days	Control	0.5 Co	3.0 Co
<i>D. brightwellii</i>			
4	0.07	0.41	2.72
6	0.04	0.43	1.72
8	0.02	0.24	0.73
<i>P. minimum</i>			
4	0.08	0.32	1.72
11	0.05	0.45	1.33
16	0.04	0.47	0.54

$\mu\text{g l}^{-1}$) was not affected by the different additions and no significant differences in chlorophyll *a* concentrations were observed among the treatments (Fig. 4).

Growth rates based on cell numbers were calculated for the dinoflagellate and for the diatom during the exponential phase of growth according to the following formula: $\mu = (\log_2 N - \log_2 N_0)/t$, where N_0 represents the total number of cells on Day 3, N is the cell number on Day 9 and $t=6$ days.

Growth rates for the diatom *D. brightwellii* (Table 2) were significantly higher ($p < 0.05$, Mann-Whitney U-test) in the controls than in the treatments where cobalt (as a salt) was added in concentrations of 0.5 nM and 3.0 nM. The same tendency was observed for the treatment with additions of cobalt as vitamin B₁₂. The controls of the treatment with additions of cobalt together with EDTA were only significantly higher than that treatment with 3.0 nM of cobalt added together with EDTA.

Growth rates for the dinoflagellate *P. minimum* (Table 1) were significantly lower ($p < 0.05$, Mann-Whitney U-test) in the controls than in the treatments with 0.5 and 3.0 nM of cobalt additions. For the different treatments of cobalt+EDTA and vitamin B₁₂ additions, the growth rates were only significantly higher ($p < 0.05$, Mann-Whitney U-test) when 3.0 nM of cobalt was added together with EDTA and 3.0 nM added vitamin B₁₂ treatment.

GRANÉLI and RISINGER (1994) have studied the effects of additions of cobalt (alone or

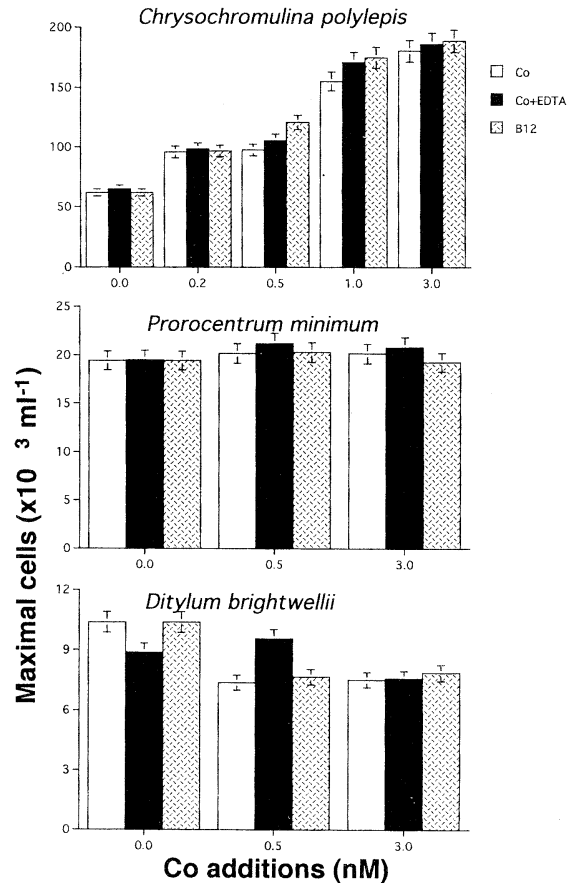


Fig. 5. Maximal cell densities for the cultures of *C. polylepis*, *P. minimum* and *D. brightwellii* grown at different additions of Co, Co+EDTA and vitamin B₁₂. *C. polylepis* figure is redrawn from GRANÉLI and HARALDSSON (1993).

together with EDTA or as B₁₂) on the toxic prymnesiophycean flagellate *Chrysochromulina polylepis*. The authors have shown that cell numbers of *C. polylepis* increased more or less linearly with additions of cobalt increased from 0 to 1.0 nM. An addition of 3.0 nM of cobalt only increased cell number accumulation slightly over the cell numbers produced at the 1.0 nM addition.

Comparing to our study (Fig. 5), the response of the three algae to the different cobalt additions was not similar. It was observed that not only cell densities were higher compared to the other two algae, but also their chlorophyll accumulation and growth rates as well (see also GRANÉLI and HARALDSSON, 1993).

4. Discussion

Cobalt (as cobaltacetate or vitamin B₁₂) favours the biomass accumulation of the prymnesiophycean flagellate *C. polylepis* (GRANÉLI and RISINGER, 1994). In that experiment cobalt concentrations up to 1.0 nM increased significantly the cell yields of the flagellate. In addition, the produced maximal cell numbers of *C. polylepis* increased proportionally to increasing cobalt (added as cobaltacetate or as vitamin B₁₂) levels.

Our results in the present study show that the two tested species were affected in different ways by cobalt additions. The cell yield and chlorophyll accumulation of the diatom *D. brightwellii* were inhibited by the three different forms of added cobalt, while the cell yield and chlorophyll accumulation of the dinoflagellate *P. minimum* were not affected by any of the three different forms of cobalt additions.

For both tested species, cobalt (as cobaltacetate) concentrations were lower in water filtered from samples in the middle or at the end of the experiments compared to samples taken at the beginning (Table 1), indicating that both algal species were able to take up cobalt from the media, independently of the treatment. Cobalt concentrations in the treatments where originally 0.5 and 3.0 nM of cobalt was added, decreased respectively 42 % and 73 % from Day 4 to Day 8 for the diatom. For *P. minimum*, a slight increase in cobalt concentrations was observed in the filtrates from Day 1 to Day 16 in treatments where 0.5 nM cobalt was originally added. However, a decrease of app. 69 % was observed in treatments with original additions of 3.0 nM of cobalt. We do not have data on the uptake rates for the two tested species, but some studies have shown that the uptake of two radioactive forms of cobalt, (⁶⁰CoCl₂ and ⁵⁷Co-cobalamine) by diatoms is very and essentially complete after 30 hours (NOLAN *et al.*, 1992). According to FISHER *et al.* (1983) this is supposed to be a typical pattern of accumulation of metal ions by phytoplankton. PRICE and MOREL (1990) have shown that cobalt stimulated the growth rates of the diatom *Thalassiosira weissflogii* after the third day of incubation. In addition, some authors (ZHOU and

WANGERSKY, 1989) have also considered the importance of the dissolved organic matter (DOM) released by phytoplankton during the exponential and stationary phases of growth in cultures. DOM is able to chelate trace metals, including cobalt (ZHANG *et al.*, 1990), and form complexes which can be retained by 0.45 μm membrane filters. In our experiments, there is also a possibility that cobalt may have been bound to cells or to DOM released by cells, during the exponential and stationary phases. Thus, the total cobalt concentrations in the filtrates could have been underestimated. But, to what extent these extracellular metabolites exuded by phytoplankton may influence the medium chemistry and trace elements concentration, is still uncertain.

A chelating agent, in general, has two main functions in algal culture medium. It either keeps trace metals soluble and thus available to algae, or it reduces the toxicity of some metals, such as copper. EDTA is known as the most widely used organic synthetic chelator in algal cultures, and was used in our experiments as a chelator for cobalt. We added 5×10^{-7} M of EDTA together with different cobalt concentrations. This EDTA concentration is in the range of that suggested by JOHNSTON (1964), who recommended a use of at least 10^{-7} M of EDTA to support algal growth. In our studies, as expecting, the biomass accumulation (expressed as cell yield or as chlorophyll *a* concentrations) of the diatom was significantly higher in the treatments to which cobalt was added with EDTA than in the treatment with only cobalt (added as cobaltacetate or vitamin B₁₂). We believe that the added concentrations of EDTA was enough to alleviate the toxic effect of cobalt on the growth of the diatom. *P. minimum* did not have its maximal cell yield significantly affected neither by increasing inorganic cobalt or vitamin B₁₂ additions, nor by adding cobalt together with EDTA.

It has been shown that additions of high concentrations (up to 10^{-5} M) of strong chelating agents, such as EDTA, may decrease phytoplankton growth rates and reduce the concentrations of free metal ions in solutions to very low levels (JACKSON and MORGAN, 1978). Trace metal bioavailability to phytoplankton may be

determined not only by the concentration of the different chemical species of the metal but also by the relative concentration of cells and chelators in the medium (PRICE *et al.*, 1988 1989). The relatively low growth rates for the two tested species during our experiments (less than 0.25 doublings day⁻¹, for all the treatments), can not entirely have been due to a possible toxic effect of cobalt or EDTA when they were added alone.

Problems concerning sampling procedures in the field and in laboratory studies, as well as contamination of samples, are known to have introduced significant errors in studies of phytoplankton-trace metal interactions. We have chosen to use North Atlantic offshore water in our experiments, as it contained only 0.02 nM of cobalt. Due to the great volume of water required for the experiments we have autoclaved the Atlantic water using a standard laboratory autoclave, which is known as a source of contamination for some trace metals (PRICE *et al.*, 1988-1989). In addition, the cobalt concentrations in the control flasks were at the beginning (Day 1) of both experiments 0.08 nM, suggesting that a relative low contamination of about 0.06 nM must have occurred.

Effects of vitamin B₁₂ additions on phytoplankton growth

The growth rates and cell densities of the diatom *D. brightwellii* were negatively affected by increasing levels of vitamin B₁₂ during the experiment. However, this inhibition is contradictory to the findings of GUILLARD and CASSIE (1968), who stated that *D. brightwellii* is a B₁₂-requiring species. In general, 80 to 90 % of the dinoflagellates are vitamin B₁₂-requirers. *P. micans*, e.g. requires B₁₂ and biotin for growth. ACHIHA and IWASAKI (1990) have studied the growth characteristics of *Alexandrium tamarense* and observed that this dinoflagellate needed 0.005 nM of vitamin B₁₂ to be able to grow in cultures.

As stated by some authors (see e.g. DROOP, 1968; PINTNER and ALTMAYER, 1979; SWIFT, 1980), media of algal monocultures in stationary phase can contain a substance that is able to bind vitamin B₁₂. This substance is found in greater concentrations in monoalgal cultures

that reach very high densities, such as diatoms. Once bound, vitamin B₁₂ can not be taken up by the algal cells, even in such small amounts that the cells require. This inhibition can be overcome by adding an excess of vitamin B₁₂ (SWIFT, 1980). However, should the concentrations of vitamin B₁₂ reach too high levels, the algal growth rates might once again be inhibited.

Vitamin B₁₂ is found in surface oceanic waters only in very low concentrations (from app. 10⁻⁵ to 10⁻³ nM). Inshore waters and estuaries have higher concentrations of vitamin B₁₂. In some areas such as the Gulf of Maine (SWIFT, 1981), concentrations range from 0.1 to 1.9 ng l⁻¹ ($\approx 7.3 \times 10^{-5}$ to 1.4×10^{-3} nM). In other coastal regions such as Long Island Sound, concentrations may reach as high levels as 16 ng l⁻¹ (1.1×10^{-2} nM). Our additions of vitamin B₁₂ by far exceed the concentrations found in natural waters. Thus, the added high B₁₂ concentrations could explain the inhibition in growth rates and cell yields observed for the diatom *D. brightwellii*. We accordingly believe that high additions of vitamin B₁₂ could lead to a decrease in the growth of *D. brightwellii* in offshore waters, since this type of water was the one we used in the experiments. However, the dinoflagellate *P. minimum* did not show any significant negative response to the increasing additions of this vitamin. In contrary, it seems that the dinoflagellate was able of using cobalt (in any of the three different forms added) to maintain themselves in the long stationary phase (almost 40 days).

In this experiment, the cell yields and chlorophyll *a* concentrations of *D. brightwellii* were inhibited at cobalt and vitamin B₁₂ additions of up to 0.5 nM. However, if a synthetic chelator is added together with cobalt, then the biomass accumulation of the diatom is significantly increased compared with the controls. The biomass of the dinoflagellate *P. minimum* was not significantly affected by any of the three forms of Co additions.

These findings agree with the hypothesis suggested by GRANÉLI and HARALDSSON (1993) that cobalt may affect phytoplankton growth in coastal waters in concentrations between 0.1 and 1 nM, which are the concentrations found

in Kattogat. Thus, phytoplankton growth in these waters may be affected both positively and negatively by cobalt additions. The same authors have discussed the possibility that atmospheric deposition of acidifying substances, through the inputs of trace metals, including cobalt, by riverine waters, can alter the balance between different phytoplankton species in coastal waters, thus promoting the formation of harmful phytoplankton blooms. A large part of the catchment area of the Kattogat/Skagerrak basin has been severely acidified during the last decades and it can therefore be pointed out that the transport of cobalt to this basin has been increased during the last 20 years (BORG, 1988).

The mechanisms that led to the *C. polylepis* bloom in Kattogat/Skagerrak in 1988 are, in general, poorly understood. According to MAESTRINI and GRANÉLI (1991), *C. polylepis* may have found favorable growth conditions: a shortage of silica, sufficient amounts of inorganic nitrogen and cobalt. GRANÉLI and RISINGER (1994) have shown that *C. polylepis* has a cell quota of 0.6 fg Co. Thus, the concentrations of cobalt found in the Kattogat would be sufficient to promote cell densities of up to 20×10^6 cells l⁻¹. Considering that during the bloom in 1988, *C. polylepis* reached densities of 200×10^6 cells l⁻¹, the hypothesis that cobalt may control the phytoplankton speciation in Kattogat/Skagerrak can not be excluded.

It has been shown that cobalt can enter into different geochemical and biological interactions (BRULAND *et al.*, 1991) depending on its chemical speciation, i.e. in which chemical form cobalt could be found in natural waters. The determination of the chemical speciation of trace metals in natural waters and in laboratory studies has recently advanced substantially. Further research on chemical speciation will be necessary in order to try to understand the role of cobalt in phytoplankton growth in laboratory as well as in natural conditions.

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A three-dimensional numerical model of tide and tidal current in the Gulf of Tongking

Dinh-Van MANH* and Tetsuo YANAGI*

Abstract: On the basis of the finite difference method and the vertically σ -stretched transformation, a 3-D numerical model is established to calculate the tide and the tidal current as well as the tide-induced residual flow in the Gulf of Tongking. The model is calibrated by using the data at the tide gauge stations as well as from satellite observation. The most important tidal characteristics of 4 major constituents K_1 , O_1 , M_2 , and S_2 are reproduced well. Next the tide-induced residual flows due to K_1 and M_2 tides are calculated. The strongest residual flow of about 10 cm/s in the case of K_1 tide occurs in the south-west coastal zone of Hai-Nan Island.

1. Introduction

The Gulf of Tongking, situated between Hai-Nan Island of China and the north coast of Vietnam, is one of the two largest gulfs in the South China Sea. This is a rather shallow sea

area with the average depth of about 45m and the maximum one of 100m at the mouth (Fig. 1). It is known that the tidal regime is diurnal nearly in the whole gulf (HUANG *et al.*, 1994). The tidal amplitude is changed noticeably and the largest one reaches 2.5m at the head of the gulf.

Up to now some studies on the numerical simulation of tide in the South China Sea as well as in the gulf of Tongking have been carried out (THUY, 1969; HUANG *et al.*, 1994). In these studies the elliptical equation system without friction term or the 2-D horizontal shallow water equations were solved, therefore the vertical structure of tidal currents has not been revealed yet.

In this paper, a 3-D numerical model based on the 3-D Saint Venant equation system (NIHOUL and JAMART, 1987) is used to simulate the propagation of tidal wave as well as to consider the tidal currents and the tide-induced residual flow in the Gulf of Tongking.

2. Governing equations and solving procedure

It is common in tidal models to make some simplifying approximations in the equations of fluid motion. The fluid is assumed to be incompressible. The vertical momentum equation can be approximated by the hydrostatic pressure equation, that is a hydrostatic approximation. With these assumptions, the continuity equation and the horizontal momentum

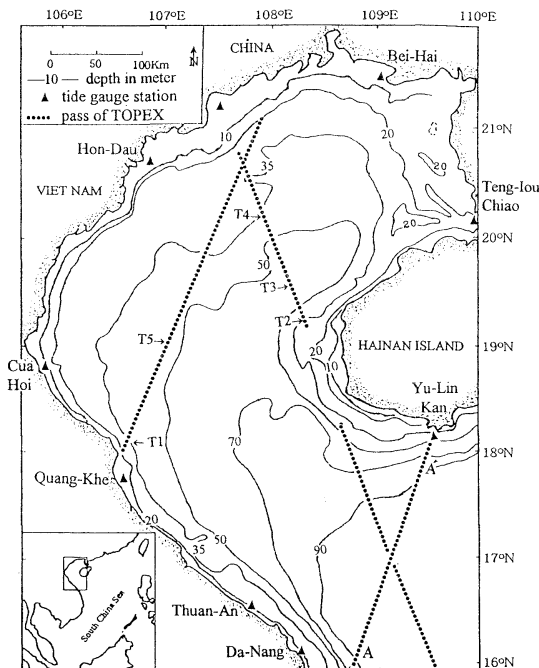


Fig. 1. Geometry of the Gulf of Tongking and the observed data locations.

*Department of Civil and Ocean Engineering
Ehime University, Matsuyama 790, Japan

equations take the following forms :

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (1)$$

$$\frac{\partial u}{\partial t} + \frac{\partial(uu)}{\partial x} + \frac{\partial(uv)}{\partial y} + \frac{\partial(uw)}{\partial w} - \Omega v = -g \frac{\partial \zeta}{\partial x} + A_h \frac{\partial^2 u}{\partial x^2} + A_h \frac{\partial^2 u}{\partial y^2} + \frac{\partial}{\partial z} \left(A_v \frac{\partial u}{\partial z} \right) \quad (2)$$

$$\frac{\partial v}{\partial t} + \frac{\partial(vu)}{\partial x} + \frac{\partial(vv)}{\partial y} + \frac{\partial(vw)}{\partial w} - \Omega u = -g \frac{\partial \zeta}{\partial y} + A_h \frac{\partial^2 v}{\partial x^2} + A_h \frac{\partial^2 v}{\partial y^2} + \frac{\partial}{\partial z} \left(A_v \frac{\partial v}{\partial z} \right) \quad (3)$$

Here x, y, z is a Cartesian coordinate with the z axis pointing vertically upwards and the xy -plane being the undisturbed position of the water surface. u, v, w are x, y, z velocity components, respectively ; $\zeta(x, y, t)$, height of the water surface above the mean sea surface; Ω , Coriolis parameter ($=2\omega \sin \phi$, ω is the angular velocity of rotation of the earth ; ϕ is latitude); g ($=980 \text{cm/s}^2$), the acceleration due to gravity ; and A_v, A_h , vertical and horizontal eddy viscosities, respectively.

In addition to the above equations, there are boundary conditions at the sea surface $z=0$, at the bottom $z=-h$, and at the lateral boundaries. They are

$$\text{at } z=0 : \frac{\partial \zeta}{\partial t} + u \frac{\partial \zeta}{\partial x} + v \frac{\partial \zeta}{\partial y} - w = 0, \quad (4)$$

$$\rho A_v \frac{\partial u}{\partial x} = 0, \quad \rho A_v \frac{\partial u}{\partial z} = 0 \quad (5)$$

$$\text{at } z=-h : u \frac{\partial h}{\partial x} + v \frac{\partial h}{\partial y} + w = 0 \quad (6)$$

$$\rho A_v \frac{\partial u}{\partial z} = \tau_x^b, \quad \rho A_v \frac{\partial v}{\partial z} = \tau_y^b \quad (7)$$

At the solid boundary: The velocity component normal to this boundary is suppressed :

$$V_n = 0, \quad (\vec{n} \text{ is the unit outward vector}) \quad (8)$$

At the open boundary: The sea water level is prefixed on the basis of observational results :

$$\zeta = f(x, y, t) \quad (9)$$

The vertical viscosity A_v , according to the Prantl's mixing length theory, is taken as

$$A_v = A_{v0} + l^2 \sqrt{(\partial u / \partial z)^2 + (\partial v / \partial z)^2}, \quad l = k_0(z+h+z_0) [1 - (z+h)/h] \quad (10)$$

where k_0 ($=0.4$) is the Karman constant ; z_0

($=10 \text{cm}$) is the sea bed roughness length ; A_{v0} is a small number to prevent the case of dividing by zero during the calculation.

The components of bottom friction stress (τ_x^b, τ_y^b) are got the following form :

$$(\tau_x^b, \tau_y^b) = \beta \sqrt{(u^2 + v^2)} (uv) \quad (11)$$

where β is the bottom friction coefficient ($=0.026$).

In order to solve the above mentioned equation system to determine velocity components as well as sea water level, the finite difference method is applied. Some parameters of the numerical model are taken as : the horizontal space steps equal to $1/6$ degrees ; the number of layers is 6 ; the horizontal eddy viscosity, $A_h = 10^6 \text{cm}^2/\text{s}$. The solving procedure at each time step is described as follows :

Firstly, the depth averaged velocity components and sea water levels are determined. By integrating the above equations over the range from $z=-h$ to $z=\zeta$ and using the boundary conditions of (4) to (7), the modified shallow water equations are obtained. These equations with the boundary conditions can be solved by one of the existing two dimensional algorithms, and in this computation an alternative direction implicit (ADI) Scheme (RAMMING and KOWALIK, 1980) is employed.

Secondly, for 3-D velocity components computation, a vertically σ -stretched grid (NIHOUL and JAMART, 1987) is applied with $\sigma = (z+h)/(h+\zeta)$ and hence σ varies between 0 and 1. Therefore the spacing steps on each vertical grid line are regular and the accuracy of bathymetry approximation is improved. Using the depth mean velocity components and sea water levels determined in the first stage, as well as the boundary conditions of (5) and (7) the equations of (2) and (3) are approximated by a finite difference scheme, implicit in the vertical direction and explicit in the horizontal ones (LARDNER, 1988), in order to get a pair of recursive formulae on each vertical grid line

$$u_{j+1} = R_j u_j + S_j v_j + Q_j^x, \quad v_{j+1} = S_j v_j + R_j u_j + Q_j^y$$

where j denotes the j th vertical grid level. Coefficients R_j, S_j, Q_j^x, Q_j^y are computed recursively downwards from $j=N$ ($z=\zeta$) to $j=1$ ($z=-h$). Then the horizontal velocity components u_j, v_j are computed recursively upwards from j

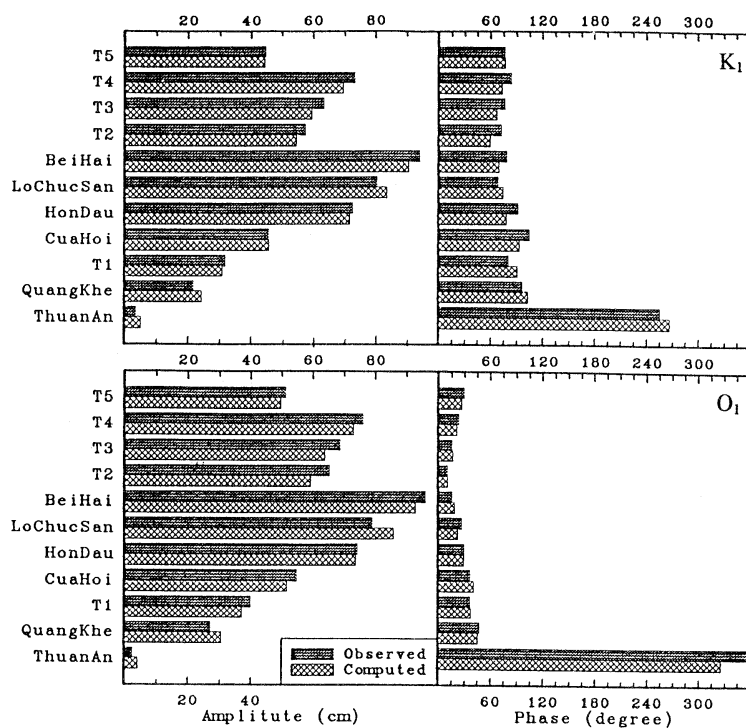


Fig. 2. The observed data and computed results of K_1 tide (above) and O_1 tide (below) at the stations.

$=1$ to $j=N$.

Lastly, the vertical velocity component is obtained by integrating the equation (1) from bottom to surface.

It is known that tide-induced residual flow plays an important role in the long-term transport of substances. It may be obtained by averaging the tidal current over one tidal cycle.

3. Results

Data used for the open sea boundary condition and the model calibration are the harmonic constants of 4 major constituents K_1 , O_1 , M_2 , S_2 at the tide gauge stations and from satellite observation, TOPEX (YANAGI *et al.* 1997). At the open sea boundaries, the sea surface oscillations due to each of the above mentioned constituents are given by using the data along the AA' pass of TOPEX and at 3 tide gauge stations Da-Nang, Yu-Lin-Kan and Teng-Iou-Chiao. The data at 6 other stations and 5 points, denoted by T1, ... T5, of TOPEX are employed for the calibration. Among these, Cua-Hoi, Hon-Dau and Bei-Hai are 3 standard tide

gauge stations. The data locations are shown in Fig. 1.

a. Diurnal Tides:

The comparison between the calculated results and the observed data of two diurnal tides K_1 and O_1 are presented in Fig. 2. For K_1 tide, the maximum absolute error of amplitude is less than 4 cm (6.2%), and of phase is 13.5° (54 minutes). In the case of O_1 tide, the error of amplitude is larger, reaches 6.7 cm (8.5%), but the errors of phase is smaller, not exceed 5° (20 minutes), except at Thuan-An.

The amplitude and phase distributions of these constituents obtained from the numerical model are displayed in Fig. 3. An amphidromic point exists near the Thuan-An in both two cases. Tidal amplitude increases gradually in the south-north direction and gets the maximum value, greater than 80 cm, at the head of the gulf. Tidal ellipses of K_1 constituent at three layers; the upper (-5 m), middle (-20 m) and lower layers (-50 m), are expressed in Fig. 4. The predominant direction of tidal currents is parallel to the shoreline. The strongest

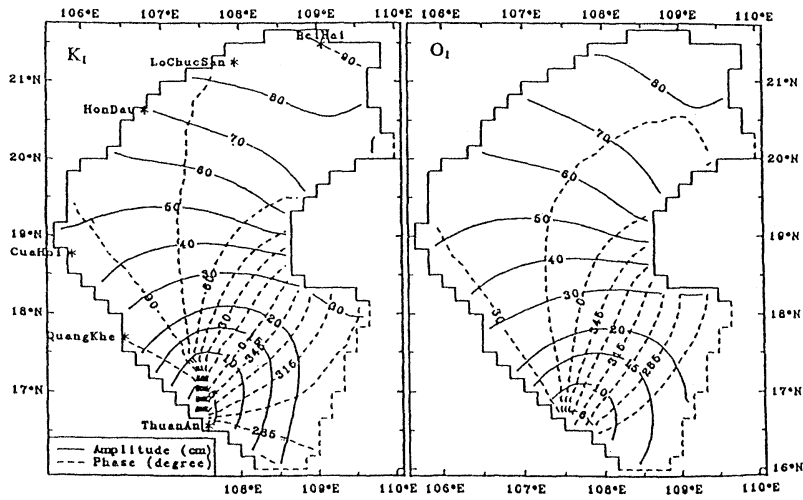


Fig. 3. The calculated co-range and co-phase charts of K_1 tide(left) and O_1 tide (right).

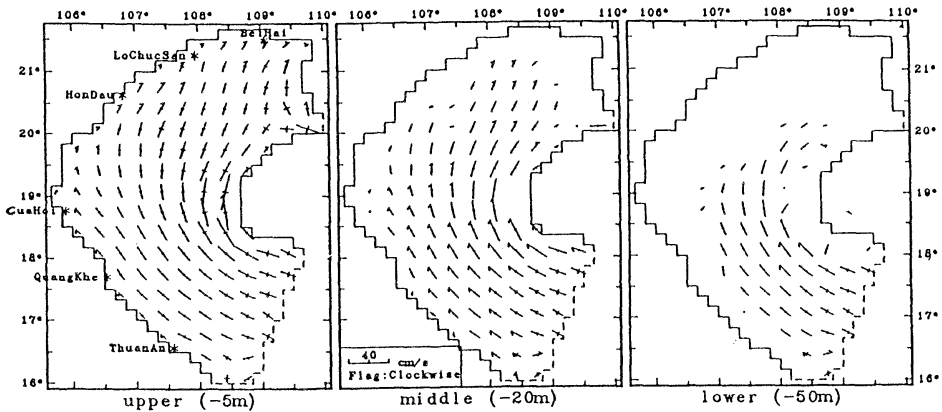


Fig. 4. The calculated tidal ellipses of K_1 tide at three layers.

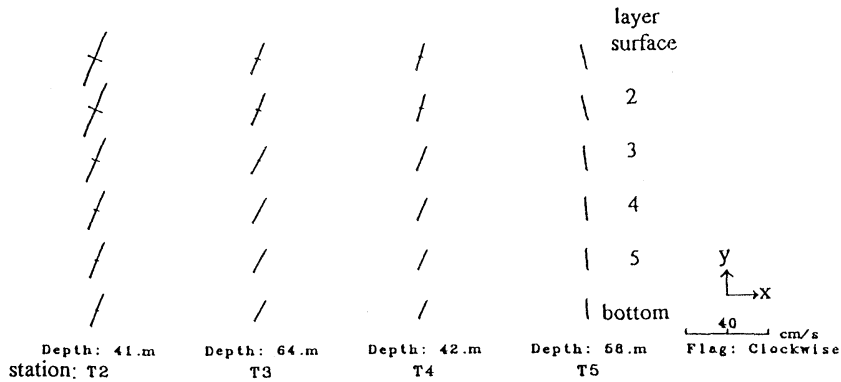


Fig. 5. The calculated tidal ellipses of K_1 tide in the vertical direction at some points.

currents (reach 60cm/s) occur in the southwest coastal zone of Hai-Nan Island. The rotational direction of tidal ellipse is mainly

clockwise. The major axes of tidal ellipses rotate slightly in clockwise direction downwards as shown in Fig. 5. The comparison between

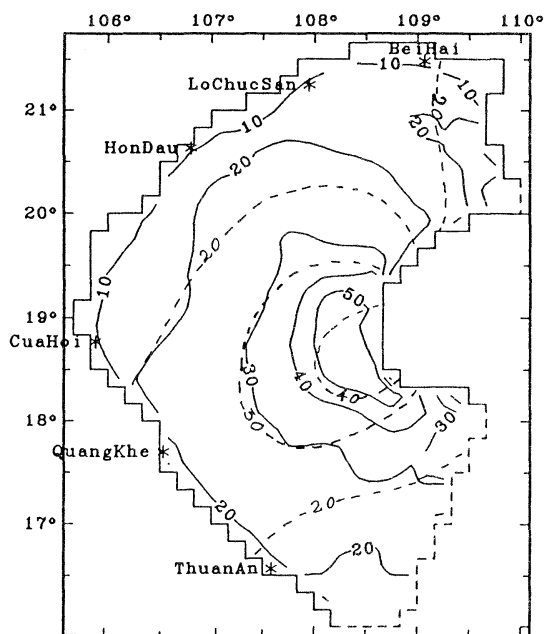


Fig. 6. The Maximum current velocity distributions of K_1 constituent. ---observed (FANG, 1986), —calculated.

the observed distribution of maximum current velocity

(FANG, 1986) and the calculated one shows that the calculated currents well reproduce to the observed data in quantity as shown in Fig.6. The O_2 tidal ellipses are similar to the K_1 ones (not presented here).

b. Semi-Diurnal Tides :

Figure 7 presents the amplitudes and phases of M_2 and S_2 tidal waves from observation as well as the model results. It is shown that the model results agree with the observed data. In the case of M_2 , the maximum absolute error in amplitude is 3cm (32%) at T2, and in phase is 22° (45 minutes) at Thuan-An. For S_2 tide, with the amplitude about 2 times smaller than M_2 , the phase errors at almost stations are a little greater (up to 24°).

The amplitude and phase distributions of semi-diurnal tides are presented in Fig.8. The maximum amplitude region is the northeastern part of the gulf. However, there is another region having relatively large tidal amplitude, around Cua-Hoi. The amplitude near Hon-Dau

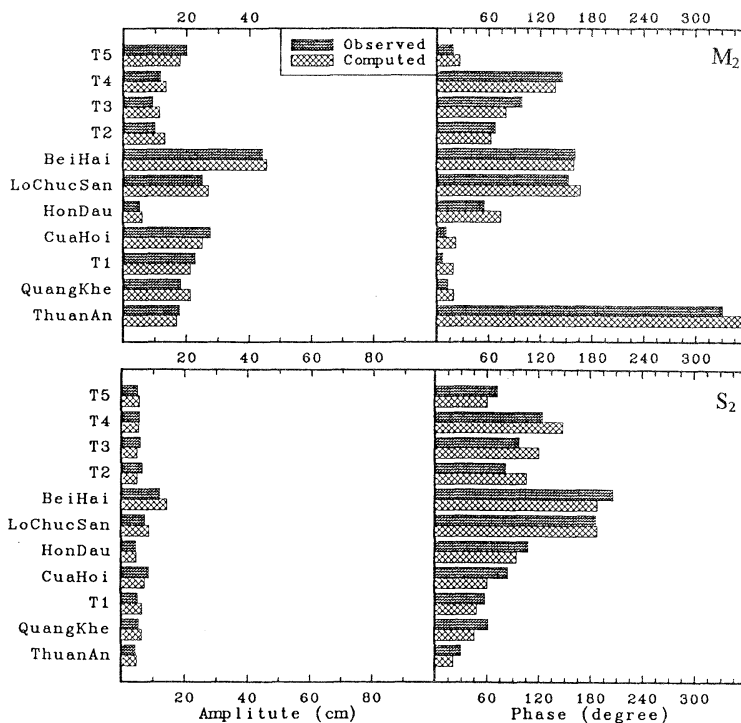


Fig. 7. The observed data and computed results of M_2 tide(above)and S_2 tide(below)at the stations.

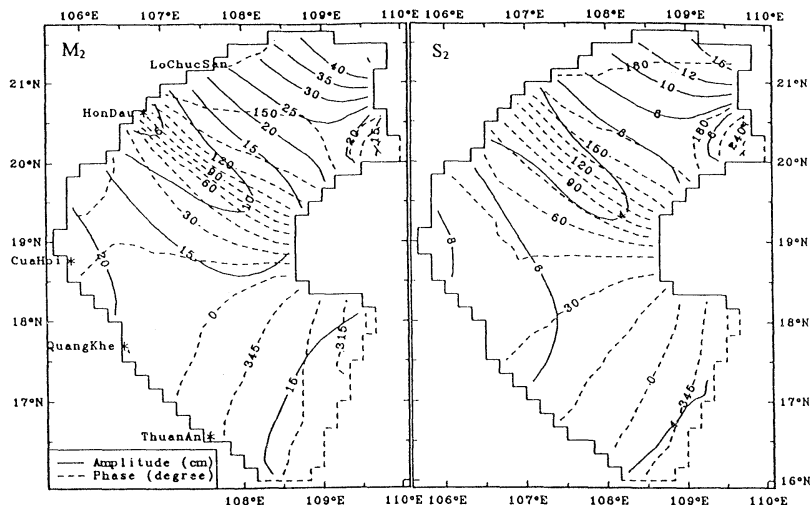


Fig. 8. The calculated co-range and co-phase charts of M_2 tide (left) and S_2 tide (right).

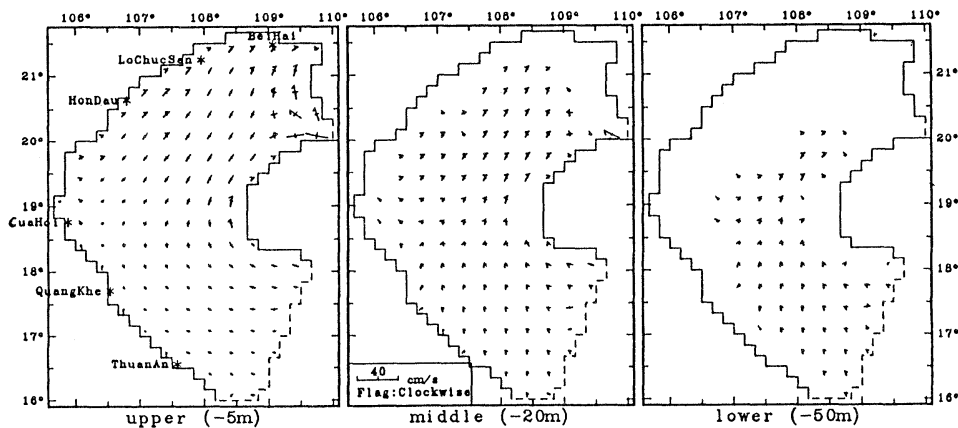


Fig. 9. The calculated tidal ellipses of M_2 tide at three layers.

region decreases. In Fig. 9 the tidal current ellipses of M_2 constituent are shown. In this case the tidal currents mainly rotate in the counter-clockwise direction. The S_2 tidal currents have the similar pattern to the M_2 ones but smaller in magnitude.

c. Tide-induced residual flows

The tide-induced residual flows are calculated in two cases, those due to K_1 tide and M_2 tide. The residual flows at three layers due to K_1 tide are displayed in Fig. 10. It is shown that the strongest flow of about 10cm/s occurs at the middle layer in the south-west coastal zone of Hai-Nan Island, where the K_1 tidal currents are the strongest. Another region with the considerable strong flow is the coastal zone from

Thuan-An to Quang-Khe of Vietnam. In the northwestern part of the gulf the flow speed is small. There is a large anti-clockwise eddy with the center located at $107^{\circ} 50'E$ and $18^{\circ} 10'N$. Besides, some other small eddies exist in the northern part of the gulf. The M_2 tide causes a weaker residual flow. The remarkable residual flow due to M_2 tide is along the shore from Hai-Nan Strait to Thuan-An. The flow is quite small offshore and in the coast zone of Hai-Nan Island as shown in Fig. 11.

4. Discussion

Obviously, the tidal wave propagates into the Gulf of Tongking mainly through the southern open boundary. The tidal amplitude

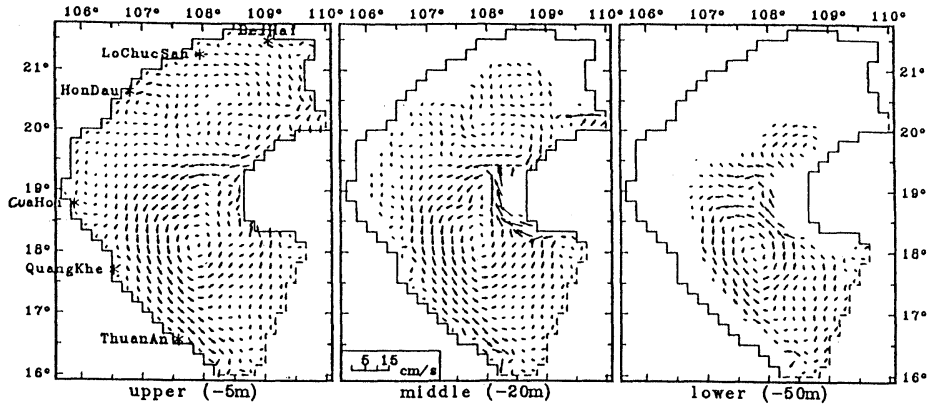


Fig. 10. The calculated residual flow chart caused by K_1 tide at three layers.

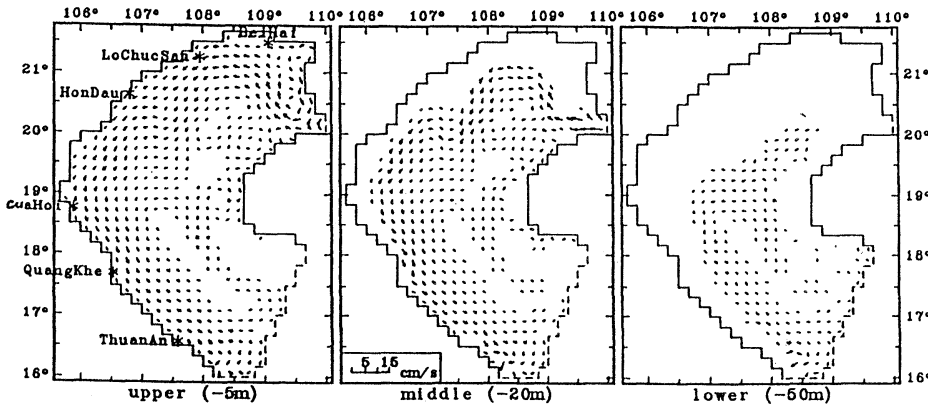


Fig. 11. The calculated residual flow chart caused by M_2 tide at three layers.

is increased due to decreasing of the water volume. On the other hand, the wave is reflected by the shore line and this process is repeated complicatedly in a semi-closed sea area as the Gulf of Tongking. Therefore, the tidal amplitude is the highest at the head of the gulf and this part of the shore line plays the most important role in the wave reflection. As a result, an amphidromic point of the diurnal tidal wave of K_1 and O_1 exists in the coastal zone of Thuan-An. In other word, the incident wave amplitude is canceled by the reflected one there. In the cases of the semi-diurnal waves, whose wave lengths are about 1/2 of the diurnal ones, there is no amphidromic point. However, a smaller amplitude region appears in the coastal zone of Hon-Dau, i.e. about a half of the distance from Thuan-An to the head of the gulf, because in this region the tidal amplitude is influenced strongly by other different parts of

the shore line as well as the Hai-Nan Strait.

The horizontal distribution of tidal type $F \left(= \frac{H_{K1} + H_{O1}}{H_{M2} + H_{S2}} \right)$ obtained from the numerical model is drawn in Fig. 12. It shows that nearly in the whole gulf, except near Thuan-An, the tidal type is diurnal ($F > 1.25$). The remarkable amplitude increase of the diurnal tides in comparison with the semidiurnal ones during propagating in the gulf is due to the resonant phenomenon. This is suitable to the results of a study on natural oscillation of the Gulf of Tongking (NINH and DUJET 1995): one of the natural oscillating periods of the Gulf of Tongking is about 19.6 hours, i.e. near the diurnal period.

In this model a horizontal grid size of about 18km is used, therefore it is impossible to include the local topography effects in detail. The obtained results show that the calculated

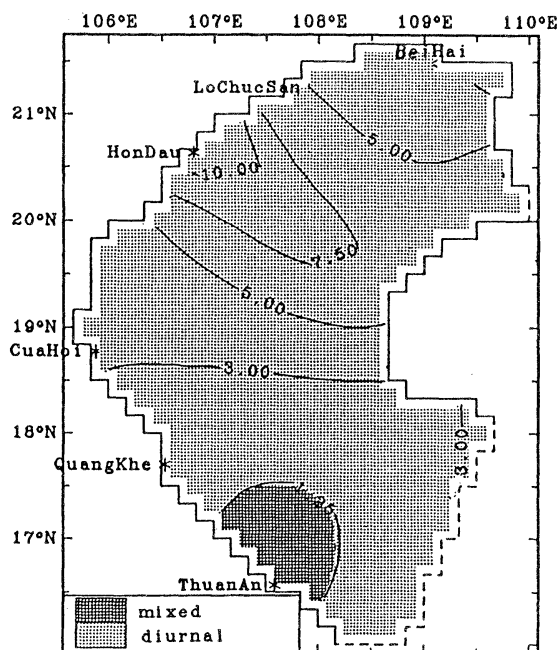


Fig. 12. The horizontal distribution of tidal type $F = (H_{K_1} + H_{O_1}) / (H_{L_2} + H_{S_2})$.

results at some stations are worse than at others, for example, at Lo-Chuc-San. One of reasons may be the complication of local topography. Because of the lack of tidal current information, the tidal currents are assessed in only quantity. However, on the basis of the obtained results it can be said that the model simulates well the main characteristics of tidal process in the Gulf of Tongking.

In this study the TOPEX data are exploited. Therefore, the calculated results are verified not only at the tide gauge stations but also at some offshore points. Furthermore, the 3-D structure of tidal currents are taken into account. These have not been considered in the former studies (THUY, 1969, HUANG *et al.*, 1994) yet.

5. Conclusion

The 3-D numerical model of tide and tidal currents in the Gulf of Tongking is established. The obtained results are as follows.

1-The co-range and co-phase charts of 4 major constituents K_1 , O_1 , M_2 , S_2 are reproduced well. As a result, the chart of tidal type is drawn. It

shows that the tidal type in the gulf is diurnal, except near Thuan-An.

2-The 3-D characteristics of tidal current in the gulf are simulated. The predominant direction of tidal currents is parallel to the shore. The strongest currents occur in the south-west coastal zone of Hai-Nan. This agrees well with the observed data in quantity.

3-The tide-induced residual flows due to K_1 and M_2 tidal components are calculated.

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自動イカ釣機の脱鈎と脱落防止の機構

矢田貞美*・郭海波*・戸田勝善*・中村善彦*

Mechanisms of squid falling off and preventing dropping out from jig of automatic jigging machine

Sadami YADA*, Haibo GUO*,
Masayoshi TODA* and Yoshihiko NAKAMURA*

Abstract : The mechanisms of squid falling off and preventing squid dropping out from a jig of an automatic jigging machine were theoretically analysed. The results were as follows :

1. Because of centrifugal force, the probability of squid automatically falling off from the jig on the guide roller increased when drum rotated with a faster angle velocity.
2. Hook open angle was determined according to a synthesis of squid falling off from the jig and the jigging operation effect.
3. When the hook open angle is further smaller, the catch efficiency of the jig is raised, and contributing to reduce the squid dropping out from the jig.
4. In order to prevent large size squid dropping out from the jig, the following methods were concluded to be effective by means of enlarging the jig, widening the hook, and using a multi step hook.

1. はじめに

巻上げる際にガイドローラを通過時に脱鈎しないイカは、巻取りドラムに巻込まれる。そのためガイドローラの通過時におけるイカの自動脱鈎の精度は、巻取りドラムの角速度の変動(小倉, 1991; 郭ら, 1995)による“シャクリ”と共に釣獲性能に影響を及ぼす重要な要素(五十嵐ら, 1968; 五十嵐ら, 1978; 小川, 1993)と考えられる。また、体重が軽いスルメイカに比較して、大型アカイカは巻上げ時に触腕が引裂かれたり、破断したりして着鈎したイカの20~53%は脱落し、しかもこの現象は手釣りより機械釣りの方が多(水産庁, 1993)。しかし、自動脱鈎や脱落の防止に関する機構面からの研究は見当らない。

本研究は、このような背景と問題点に着目し、自動イカ釣機における脱鈎と脱落の防止の両機構について理論的に解析し、脱落の防止方法について検討した。

2. 実験および解析方法

1) 自動脱鈎の機構解析

千葉県小湊町沖合において、円型ドラム(直径0.48m)のイカ釣機(以降、H式と称する)の操業状況を撮影したビデオ映像と、ドラムがガイドローラより高い場合を考察対象とした菱形ドラムのイカ釣機(サンメイSE-8、以降、S式と称する)におけるガイドローラ(GR)の諸寸法(両方式の直径: 0.14m)、回転数等の関係から自動脱鈎の機構について理論的に究明した。ここでは、巻上げ時に釣糸との接触摩擦力により回転するガイドローラの回転速度を釣糸の巻上げ速度で除した値を速度損失係数 κ として表示した。その際、ガイドローラと釣糸の接触角 α を変え、定角速度で回転するドラムが釣糸を巻き上げる際におけるガイドローラの回転状況を撮影したビデオ画像の解析により、ガイドローラの回転速度の平均値を試算した。

また、ガイドローラと同材質の鉄板上において鮮度の良いスルメイカを速度1.5m/sで牽引した時の牽引力 f_N をバネ秤で計測し、イカの重量 m を牽引力 f_N で除した値($=f_N/m$)を動摩擦係数 μ_1 とした。動摩擦係数 μ_1 はイカの鮮度、種類および計測条件に影響されるので、 μ_1 は真の動摩擦係数ではなく、見掛けの動摩擦係数と考え

*東京水産大学漁業工学講座

〒108 東京都港区港南4-5-7

Department of Marine Science and Technology,
Tokyo University of Fisheries, Konan 4-5-7,
Minato-ku, Tokyo 108, Japan

られる。

2) 触腕の引裂き力および破断力

Table 1 に示す鮮度の良いスルメイカを供試し、Fig. 1e および f に示すように 1 本、2 本および 3 本の針がかりした時の触腕の引裂き力および破断力をバネ秤で測定した。

3) 脱落の防止機構の解析

巻上げ時におけるイカの脱落の原因についてイカ触腕の受ける力および破断応力を解析し、針長と針径の大型

化、針笠の上下段の間隔の広化および擬餌針の多段化などによる脱落の防止機構について検討した。Fig. 1a, b, c, d および e に供試した擬餌針の各部分名称を示す。d は針径、 x は針長、 x_1 は針が触腕を貫通し突き出した長さ(以降、針の突出長と称する)、 x_2 は針先の鋭角部の長さ、 ϕ は針先角、 d_1 は針笠の上下段の間隔、 r は多段針の針笠の底部の半径、 β は針の開角度、 d_x は針の水平長、 d_y は針の垂直長である。

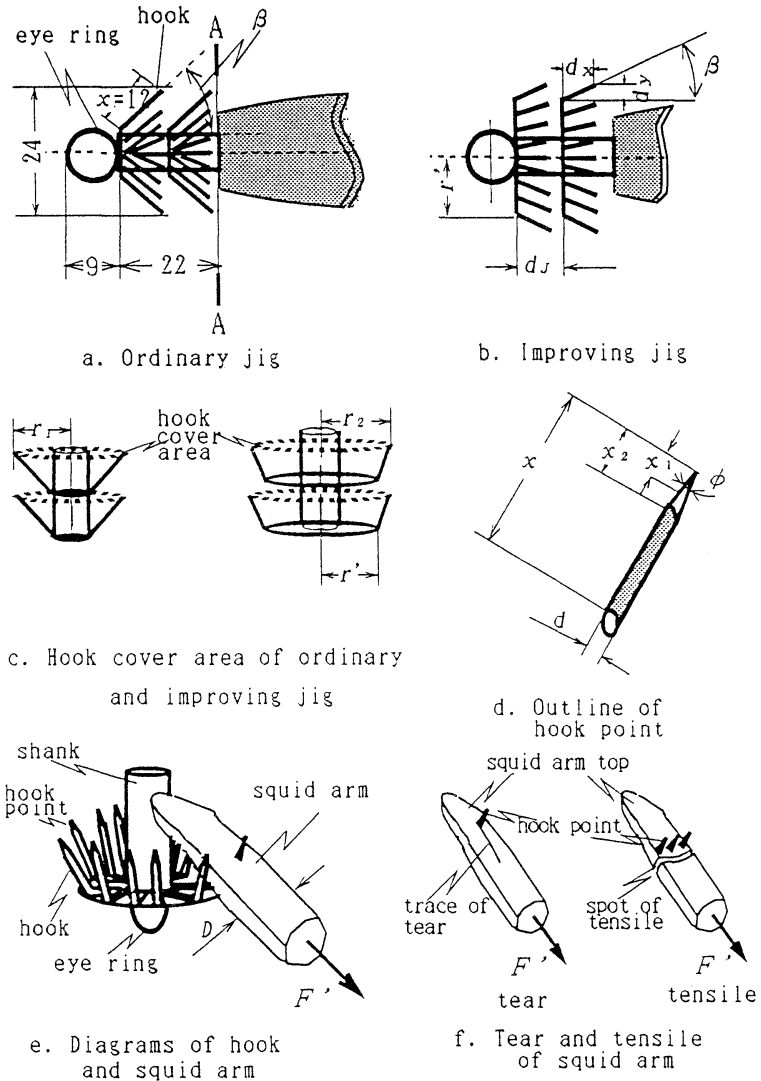


Fig. 1. Schemes of jigs and Jig hooking into squid. x : length of hook, d : diameter of hook, d_x : horizontal length of hook, r : radius of jig bottom, d_y : vertical length of hook, β : open angle of hook, r_1 : radius of ordinary jig, r_2 : radius of improving jig, D : diameter of squid arm, F' : pulling force, x_1 : length of hook cutting across squid arm, x_2 : length of hook point, ϕ : angle of hook point, d_1 : distance from upper-hook to under-hook of jig.

Table 1. Tear tensile and stress of squid arm.

Case No.	Weight (g)	Length (mm)	Stress of squid arm		
			Tear σ_{KM} (gf/mm ²)	Tear σ_{KM} (gf/mm ²)	Tensile σ_{HM} (gf/mm ²)
			(1 hook)	(2 hooks)	(3 hooks)
1	292	250	489	58.2	34.5
2	285	240	540	56.5	35.3
3	280	238	547	54.8	32.4
4	290	250	532	55.7	32.8
5	288	247	497	49.8	34.8
Average	287	245	521	55.0	34.0

Note : 1. Samples were caught fresh squids

2. Hooked position was centre of squid arm's diameter and length

3. 解析結果および考察

1) ガイドローラの回転による自動脱鉤機構

Fig. 2 に示すように、ブルワークに装備した自動イカ釣機は、ガイドローラを介してイカのかかった擬餌針と釣糸を巻上げる。Fig. 3 に示すように、巻上げ時にガイドローラによって、急激に巻上げ方向を変換するので、イカは遠心力および重力により擬餌針から自動的に脱鉤して、ネット上に落下シュートに収集され、流下して受箱に収納される。巻取りドラムが巻上げる釣糸は、ガイドローラの接触面との接触摩擦によりガイドローラを回転させる。ガイドローラを通過する釣糸の長さは瞬間的にはS式ドラムにより変動するが、本稿では平均的な長さとし、ガイドローラの角速度 ω (rad/s) は(1)式で示される。

$$\omega = \kappa \frac{\omega_1(4L_a + 2L_b)}{2\pi r} \quad (1)$$

但し、 κ はガイドローラの手速度損失係数、 ω_1 はドラムの角速度、 L_a はドラムの長辺、 L_b はドラムの短辺、 r はガイドローラの半径である。

(1)式はガイドローラの角速度 ω がドラムの角速度 ω_1 およびドラムの周長 $(4L_a + 2L_b)$ に正比例し、ガイドローラの円周 $(2\pi r)$ と反比例の関係にあることを示している。一般に、ドラムの周長はガイドローラの円周より長いので、ガイドローラがドラムより速く回転する。

長辺 L_a が 0.27m、短辺 L_b が 0.06m、ガイドローラの半径 r が 0.07m の S 式ドラムの場合において、ドラムの角速度 ω_1 を 5.30 rad/s としたガイドローラと釣糸の接触角 α とガイドローラの手速度損失係数 κ の関係を Fig. 4 に示す。ガイドローラは釣糸との接触摩擦により回転するので、ガイドローラの手速度は釣糸の巻上げ速度より

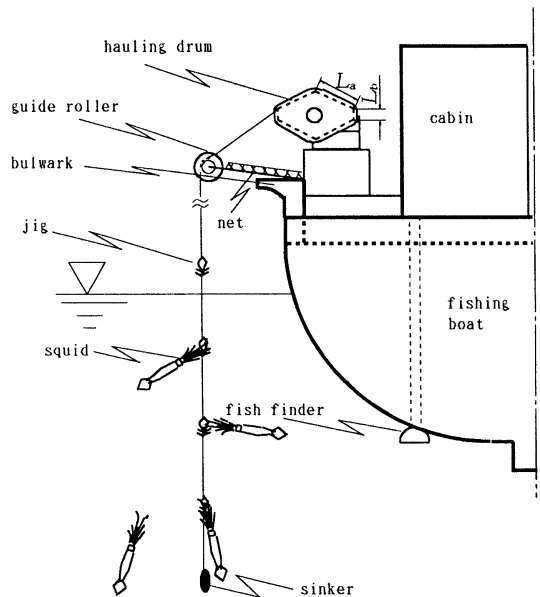


Fig. 2. Scheme of squid jigging operation. L_a : long side length of drum, L_b : short side length of drum.

遅いことになる。接触角が $0 \sim 40^\circ$ では、速度損失係数は急激に増大するが、 40° 以上では速度損失係数の増大勾配は小さくなった。即ち、速度の損失は 40° 以上になると少なくなる。ガイドローラと釣糸の接触角 α が 80° の時におけるガイドローラの手速度損失係数 κ は 0.90 であるから、(1)式によるガイドローラの手速度 ω は 13.02 rad/s となる。

ここで、ガイドローラとドラム間の距離はドラムの寸

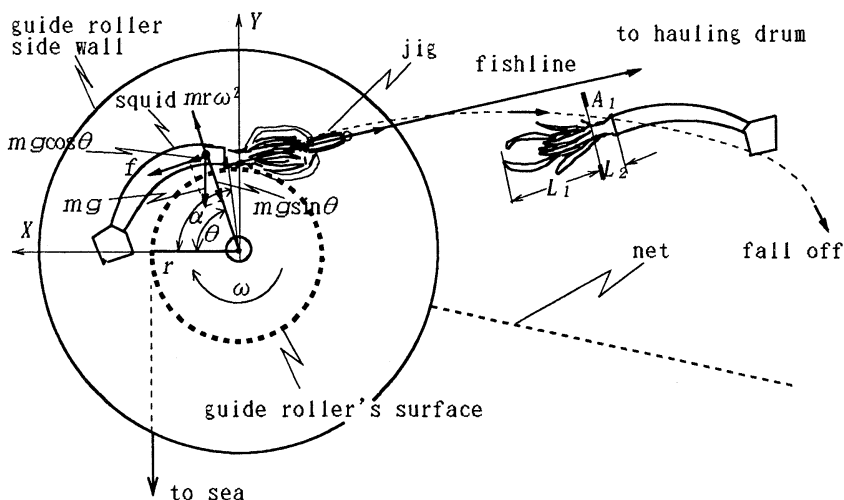


Fig. 3. Scheme of squid on guide roller and squid falling off from jig. f : frictional force, m : mass of squid, r : radius of guide roller, ω : angle velocity of drum, g : acceleration of gravity, α : contact angle between fishline and guide roller, θ : angle between the line of squid mid point with guide roller center and horizontal line with squid fall off guide roller, X : X axis, Y : Y axis, L_1 : length of squid arm, L_2 : length of squid head, A_1 : hooked area of squid head.

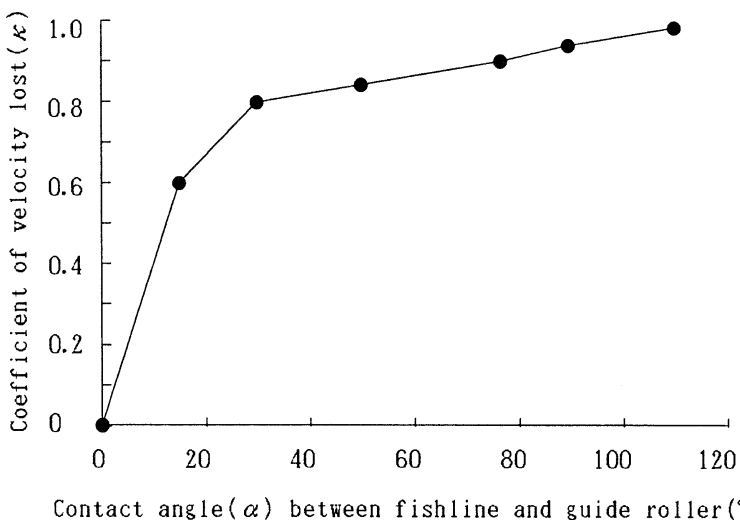


Fig. 4. Relationship between contact angle (α) and coefficient (κ) of velocity lost.

法 L_1 および L_2 に較べて相対的に大きいものとし、ガイドローラの回転数の平均値を用いて、ガイドローラの径を 0.14m、巻上げ速度を 1.5m/s とすると、ガイドローラの面に接触してから脱鉤までの間、イカに作用する重力 mg 、遠心力 $mr\omega^2$ および摩擦力 $\mu_1 (mr\omega^2 - mg\sin\theta)$ を合計した総作用力 $F(N)$ は(2)式で示される。

$$F = mg\cos\theta + \mu_1 (mr\omega^2 - mg\sin\theta) \quad (2)$$

但し、ガイドローラとの接触時におけるイカの質量を

質点 $m(kg)$ 、イカとガイドローラ間の摩擦力 f に伴う動摩擦係数を μ_1 、重力加速度を $g(m/s^2)$ 、脱鉤時におけるイカの重心とガイドローラの回転中心を結ぶ線と水平方向 X とのなす角度（以降、脱鉤角度と称する）を θ (°) とする。

イカ質点 m は遠心力 $mr\omega^2$ により法線方向に加速度 $r\omega^2$ を受け、巻上げ速度 V より速くなるので、針から脱鉤する。この時には、 F は零となるので脱鉤角度 θ は(2)式より(3)式で示される。

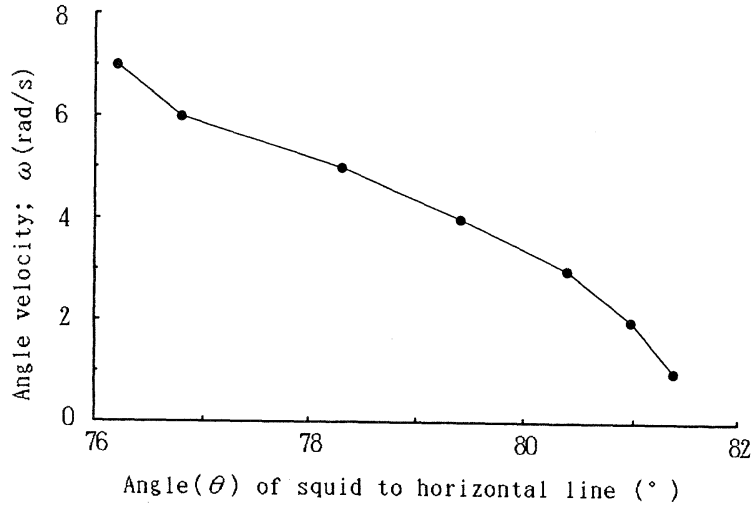


Fig. 5. Relationship between angle velocity (ω) and angle (θ) between the line of squid midpoint with guide roller center and horizontal line with squid fall off guide roller. This figure is the calculation of equation (4), calculation condition: friction factor of squid to guide roller μ_1 : 0.30, radius of guide roller r : 0.07m, acceleration of gravity g : 9.8m/s².

$$\theta = \sin^{-1} \left(\frac{r\omega^2\mu_1^2}{(\mu_1^2+1)g} \frac{\sqrt{r^2\omega^4\mu_1^4 - (\mu_1^2+1)(r^2\omega^4\mu_1^2 - g^2)}}{(\mu_1^2+1)g} \right) \quad (3)$$

(3)式より、脱鈎角度 θ はガイドローラの角速度 ω の大小によって決まる。イカの動摩擦係数 μ_1 の実測値は0.30(標準偏差:0.05)であり、 r は0.07mなので g を9.8m/s²とした場合の、(4)式により試算した脱鈎角度 θ とガイドローラの角速度 ω の関係を Fig. 5 に示す。同図は、角速度が増大すると、脱鈎角度 θ は小さくなることを示している。

これらから、ガイドローラの回転が速いと、即ち巻上げ速度が速いとイカの受ける遠心力は増大するので、脱鈎角度が小さい時、即ちガイドローラ面において早い時点で脱鈎でき、自動脱鈎の確率が高くなるものと推察される。

2) 針の開き角度 β が脱鈎に及ぼす影響

Fig. 1 a に示す擬餌針(質量約15g,長さ9.5cm)の針と針笠の軸方向とのなす角度 β (以降、針の開き角度と称する)について考察する(Fig. 2 参照)。

考察を容易にするために、ガイドローラの曲率を零と仮定し、イカと脱鈎時の放擲加速度 a_1 (m/s²)、重力加速度 g (m/s²)、イカの擬餌針の動摩擦係数 μ_2 、脱鈎角度 θ (°)とすると、針の開き角度 β (°)は(4)式で示される。

$$\beta = \tan^{-1} \left(\frac{1}{\mu_2} \left(1 + \frac{a_1}{(\cos \theta - \sin \theta)g} \right) \right) \quad (4)$$

(4)式において、イカと擬餌針の動摩擦係数 μ_2 、重力加速度 g および脱鈎角度 θ は定数と見なして良く、イカの脱鈎時の放擲加速度 a_1 は針の開き角度 β によって決まることを示している。イカの脱鈎時の放擲加速度 a_1 と針の開き角度 β の関係を、(4)式による理論値で Fig. 6 に示す。針の開き角度 β が増大すると、イカの脱鈎時の放擲加速度 a_1 は減少する。より小さな脱鈎角度 θ で脱鈎するには、放擲時に大きな加速度 a_1 を必要とするので、針の開き角度 β を小さくする必要がある。(4)式によると、 β が過小な場合にはイカは針がかりしやすい。逆に、 β が大きいとイカは針がかりし難くなるが、イカの自動脱鈎は容易になるものと推察される。

(4)式の適否を検証するため、 β を試算した。例えば、イカの擬餌針の動摩擦係数 μ_2 をイカとガイドローラ間の動摩擦係数 μ_1 と同程度の0.3に、また5~6rad/sの角速度(ω)時における脱鈎角度 θ をほぼ77°(Fig. 5 参照)とし、重力加速度 g を9.8m/s²、脱鈎時の放擲加速度 a_1 を5.0m/s²とすると、(4)式より針の開き角度 β は24.8°となる。

したがって、針の開き角度 β は釣獲対象、操業条件、自動脱鈎の良否および釣獲効果などを考慮して設定する必要がある。

3) 擬餌針の形状が脱鈎に及ぼす影響

Fig. 1 a に示す擬餌針を同図 b に示すように改造す

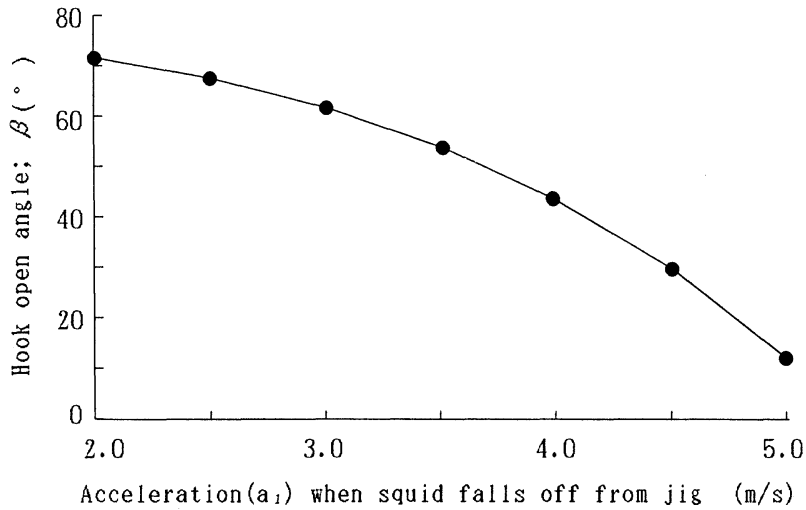


Fig. 6. Relationship between hook open angle (β) and acceleration (a_1) of squid when it falls off jig. This figure is the calculation of equation (5), calculation condition: friction factor of squid to hook μ_2 : 0.30, angle (θ) between the line of squid midpoint with guide roller center and horizontal line with squid fall off guide roller, angle of squid to horizontal line θ : 77° , acceleration of gravity g : 9.8m/s^2 .

ると、多段針の各針筈の底部の半径 r は長くできるので、針の開き角度 β を更に小さくすることが可能である。針の底部までの水平長 d_x は $x\sin\beta$ であり、針の水平長 d_x が針の開き角度 β によって決まることを示している。さらに、Fig. 1 c に示すように、半径 r の底辺を設けると、針の開き角度 β は小さくても各段の各針先を結ぶ領域が従来の擬餌針 r_1^2 より r_2^2 と増大し、イカの針がかりする機会は増大するものと推定される。

さらに、(4)式によると、このような形状の針は開き角度 β を小さくできるから、脱鈎時におけるイカの放擲加速度 a_1 は増大できるので、脱鈎機能は向上するものと推察される。

しかし、垂直長 d_w が大きいと、巻取り時に糸がかりや、糸の損傷が懸念されるので小さくする必要がある。

4) 巻上げ時における脱落の防止方法

大型アカイカを対象とした釣りでは、巻上げ時に水中抵抗で生じる水中脱落と、水面からガイドローラ (Fig. 3 参照) までの間にイカの空中噴水による急激な見掛け加重の増大、および浮力の減少による空中重量の急増による空中脱落が見られる。針がかりするイカの部位やその多少によって、脱落の早晩や多少が異なる。2本の触腕のみが針にかかっているものの脱落率は96%と高く、全腕で針を捕捉しているものは12%と少なく、全腕と頭部に針がかりしているものは脱落が見られない(小倉, 1991)。

脱落の原因には、巻上げ時に触腕が引張り破断(以降、引張り破断と称する)する場合と、引裂かれて(以降、引裂き破断と称する)脱落する場合が考えられ、この脱落の防止には、以下の方法が考えられる。

(1) 触腕の引張応力を減少させる方法

巻上げ時に水中および空中でイカの触腕にかかる荷重 P_w および P_a は、おのおの(5)および(6)式で示される。

$$P_w = ma + (mg - \rho V) + f_w \quad (5)$$

$$P_a = ma + mg + f_a \quad (6)$$

但し、 m はイカの質量、 a は巻上げ加速度、 g は重力加速度、 f_w は最大遊泳力、 f_a は巻上げ時における空中噴水の反力、 V はイカの体積、 ρ は海水密度である。

また、触腕を円形とした場合の径を D 、針にかかる腕数を n_0 、針がかりしたイカ口球部の断面積を A_1 とすると、荷重を受ける腕および頭部の総断面積 A は(7)式で示される。

$$A = \frac{n_0 \pi D^2}{4} + A_1 \quad (7)$$

(5)、(6)および(7)式より、水中および空中においてイカの腕および頭部の受ける引張応力 σ_{Hw} および σ_{Ha} は、おのおの(8)および(9)式で示される。

$$\sigma_{Hw} = \frac{ma + mg - \rho V + f_w}{A} \quad (8)$$

$$\sigma_{Ha} = \frac{ma + mg + f_a}{A} \quad (9)$$

巻上げ時における引張応力 σ_H が破断許容応力 σ_{HM} より大きい場合には触腕が破断し、脱落することになる。供試したスルメイカの触腕の中央部の平均腕径 $D12\text{mm}$ の平均破断許容応力 σ_{HM} は 34gf/mm^2 であり、即ち引張応力 σ_H が 34gf/mm^2 以上の場合には触腕が破断する。触腕が柔らかく、かつ重いアカイカ（小倉，1980）は、触腕の引張り応力 σ_H が増大するので、破断の可能性が増加することになる。

したがって、針にかかる腕および頭部の総断面積 A が増大すると、引張応力は減少し、脱落の防止性能が向上するものと考えられる。

(2) 針笠の上下段の間隔の広化による方法

2段針にかかるイカの部位は、上段針笠と下段針笠の間隔（以降、上下段の間隔と称する）に左右される。Fig. 1 e に示すように、全腕と頭部の一部が針がかりするための上下段の間隔 d_i は(10)式を満足させる必要がある。

$$L_1 < d_i < L_1 + L_2 \quad (10)$$

但し、 L_1 および L_2 はそれぞれ捕捉するために伸ばした時の触腕の長さ、およびイカ頭部の長さである。

大きなイカを釣獲する場合には、上段針笠が触腕に、下段針笠が頭部にかかるように上下段の間隔の広い2段針を使用すると、脱落を防止できるものと推察される。

しかし、針笠の上下段の間隔が広化すると、巻取り時に糸がかりや、糸の損傷が懸念されるので、このことに留意しながら上下段の間隔を設定する必要がある。

(3) 針長と針径を大型化する方法

針長の長大：Fig. 1 e に触腕が針にかかる状況を示す。応力表現のため面積表示すると、Fig. 1 e に示すように触腕に刺さった針の円柱部 $(x-x_2)$ が応力として作用する接触面積 S_1 は(11)式で示される。

$$S_1 = \frac{\pi d(x-x_2)}{2} \quad (11)$$

但し、 d は針径、 x は針長、および x_2 は針先の鋭角部の長さである。

さらに、針先端の円錐型部 (x_2-x_1) が触腕に応力として作用する接触面積 S_2 は(12)式で示される。

$$S_2 = \frac{\pi d(x_2^2 - x_1^2)}{8x_2^2} \sqrt{d^2 + 4x_2^2} \quad (12)$$

但し、 x_1 は針が触腕を貫通し、突き出た長さ（以降、針の突出長と称する）である。

(11)および(12)式より、触腕に刺さった針が応力として作用する総接触面積 S は(13)式で示される。

$$S = \frac{n\pi d}{8x_2^2} (4x_2^2(x-x_2) + (x_2^2 - x_1^2)\sqrt{d^2 + 4x_2^2}) \quad (13)$$

但し、 n は触腕にかかる針数である。

巻上げ時に、イカの触腕にかかる荷重 P は前述の(5)および(6)式で示されるので、水中および空中で触腕が引裂かれる応力 (σ_{Kw} および σ_{Ka}) は（以降、引裂き応力と称する）おのおの(14)式および(15)で示される。

$$\sigma_{Kw} = \frac{8x_2^2(m(a+g) - \rho V + f_w)}{n\pi d(4x_2^2(x-x_2) + (x_2^2 - x_1^2)\sqrt{d^2 + 4x_2^2})} \quad (14)$$

$$\sigma_{Ka} = \frac{8x_2^2(m(a+g) + f_a)}{n\pi d(4x_2^2(x-x_2) + (x_2^2 - x_1^2)\sqrt{d^2 + 4x_2^2})} \quad (15)$$

(14)および(15)式において、巻上げ加速度 a は定数なので、水中および空中における触腕の引裂き応力 σ_{Kw} および σ_{Ka} は針数 n 、針長 x および針径 d に反比例することを示している。即ち、針数 n 、針長 x および針径 d が大型化すると、水中および空中における触腕の引裂き応力 σ_{Kw} および σ_{Ka} は減少し、脱落の軽減が可能と推測される。

例えば、Table 1 に示すスルメイカの場合、触腕の引裂き破断許容応力 σ_{KM} は、針径 1.2mm の場合、かかる針数が1本では 521gf/mm^2 、2本では 55.0gf/mm^2 であったが、3本では引裂かれないで破断した。直径 12mm の触腕が 2.5kg 以上の荷重を受けると引裂き応力 σ_K は 521gf/mm^2 以上となり、引裂き破断許容応力 σ_{KM} に達するが、引張応力 σ_H は 31.8gf/mm^2 となり破断許容応力 σ_{HM} 34gf/mm^2 より小さいので破断しないことになる。したがって、針がかりする腕数が増えると破断応力は減少し、破断脱落の防止に役立つ。破断した触腕等の残骸は、針に残留するので脱落の発生を確認できるが、引裂かれた触腕等の残骸は針に残留しないので、脱落の発生の有無は確認できない。しかし、前述のように巻上げ中における脱落は、引張り破断より引裂き破断による場合が多く発生することになり、このことが実船操業のビデオ画像でも確認された。

触腕の引裂き破断の防止には、針長 x および針径 d を長大する必要がある。しかし、針が長いと糸がかりやテグスの損傷が発生したり、イカが自動脱鉤しないで巻取りドラムに巻付く機会が増大する。その結果、損傷イカや未脱鉤イカの除去のために操業を一時中断しなければならないので、針長は触腕の直径と同程度にする必要がある。

針径の増大：針径 d が太くなると、触腕の引裂き応

力 σ_k は減少するが、触腕に刺さりにくくなる。刺さりやすくするには、(16)式で示す針先の開き角度 ϕ (以降、針先角と称する、)を小さくする必要がある (Fig. 1 e 参照)。

$$\phi = 2 \tan^{-1} \left(\frac{d}{2x_2} \right) \quad (16)$$

(16)式は、針先角 ϕ が針径 d と、針先の鋭角部の長さ x_2 によって決まることを示している。針径 d が増大すると、針先の鋭角部の長さ x_2 が短い場合には、針先角 ϕ は大きくなるので刺さりにくくなる。

したがって、針径 d を太くする場合には、針先の鋭角部の長さ x_2 を増大し、イカに刺さりやすい針先角 ϕ に設定する必要があるが、実用的には限界があり、現用程度と考えられる。例えば、針径 d を1.5mmに増大すると、針先の鋭角部の長さ x_2 は改良前の1/3の4mmに、(15)式より針先角 ϕ は23.6°となる。

(4) 多段針による方法

(14)および(15)式より、触腕の引裂き応力 σ_k は擬餌針の針がかりする針数 n に反比例するので、引裂き破断応力 σ_k の減少には刺さる針数を増加する必要がある。触腕に刺さる針の応力として作用する接触面積 S は、3段針では2段針の1.50倍になる。故に、同程度の荷重を受ける場合の引裂き応力 σ_k は、3段針が2段針の0.67倍になり、かつ針の応力として作用する触腕に刺さる総断面積は増大するので脱落の防止に効果があるものと推定される。また、(4)式より針笠の多段化は脱鉤角にはほとんど影響しないものと推定される。

しかし、針笠の多段化はテグスの損傷と、シャンクの大形化に伴う曲げモーメントの増大により、Fig. 1 aに示したように、シャンクに付設している擬餌が硬い場合には、擬餌針の針柄と針笠の接続面A-A断面のせん断が危惧される。しかし、一般に3段針にすると、針数が増加するので、触腕のみにかかった場合でも針がかりする腕の数や箇所が増加するから、引裂き応力が減少する。更に、イカの腕および頭部にかかる可能性が増加するので、体重の重いイカの場合には、更に脱落の防止に有効な方法と推察される。

以上のような数種の脱落の防止方法を組み合わせると、その効果を更に高めることができるものと推定される。

4. 要 約

自動イカ釣機の自動脱鉤および脱落の防止の両機構について力学的に解析し、イカの脱落の防止方法について検討した。結果の概要は次のとおりである。

- 1) 巻上げ角速度は自動脱鉤の可否の確率に影響を及ぼす。
- 2) 針の開き角度 β は釣獲対象、操業条件、自動脱鉤の良否および釣獲効果などを考慮して設定する必要がある。
- 3) 針の開き角度 β が小さいと、自動脱鉤の機能の向上および脱落の防止に有効と推定される。
- 4) 大型イカの脱落の防止には、針長と針径の大形化、針笠の上下段の間隔の広化、および針笠の多段化等が有効と推定される。

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1995年4月21日 受付
1996年12月20日 受理

学 会 記 事

1. 1996年12月2日(月) 東京水産大学において平成8年度学会賞受賞候補者推薦委員会(第1回)が開かれ、委員長に鎌谷明善氏を選出し、推薦の方法および次回の日程を決めた。
2. 1997年1月9日(木) 東京水産大学において平成8年度学会賞受賞候補者推薦委員会(第2回)が開かれ、推薦のあった候補者の研究業績について審議の結果、松山優治氏(東京水産大学)が最適格者との結論に達し、この結果を会長に報告することとした。
3. 評議員による日本学術会議第17期会員候補者および推薦人候補者の選挙が行われた(依頼1月8日、投票締切1月31日、開票2月3日)。開票結果は次の通り。
 - 1) 投票総数23通(会員候補者は単記、推薦人候補者は連記)
 - 2) 有効投票数 会員候補者23票
推薦人 46票
 - 3) 投票結果(次点まで()内は得票数)
会員候補者 (17) 有賀祐勝
(2) 岡市友利(次点)
推薦人候補者 (9) 山口征矢
(5) 森永 勤
(3) 村野正昭(次点)
4. 1997年2月17日(月) 投票結果にもとづき日本学術会議第17期会員候補者として有賀祐勝会員、推薦人として山口征矢会員、推薦予備人として森永 勤会員を、水産学研究連絡委員会へ届け出た。
5. 新入会員(正会員)

氏名	所属・住所	紹介者
内須川正幸	㈱パスコ総合環境センター 〒158世田谷区用賀2-41-18 TEL: 03-3709-7831	松山優治
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7. 会員所属・住所等変更(正会員、受付順)
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岡市 友利 〒761 高松市上之町3-6-8-305
8. 受贈図書
L5(エル・ファイブ)11(3, 5, 6)
NTT R&D 45, 46
なつしま 146
国立科学博物館専報 29
Bulletin of the National Science Museum 22(4)
青島海洋大学学报 26(3, 4)

日仏海洋学会役員・評議員

(1996~1997年度)

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	(渉外)	佐伯和昭	降島史夫	渡邊精一			
監事	久保田穰	辻田時美					
編集委員長	山口征矢						

日仏海洋学会会則

昭和35年4月7日 制定

昭和60年4月27日 改正

平成4年6月1日 改正

- 第1条 本会は日仏海洋学会と称する。
- 第2条 本会の目的は日仏海洋および水産学者の連絡を密にし、両国のこの分野の科学の協力を促進するものとする。
- 第3条 上記の目的を実現するため本会は次の事業を行なう。
- (1) 講演会の開催
 - (2) 両国の海洋学および水産学に関する著書、論文等の相互の翻訳、出版および普及
 - (3) 両国の海洋、水産機器の技術の導入および普及
 - (4) 日仏海洋、水産学者共同の研究およびその成果の論文、映画などによる発表
 - (5) 両国間の学者の交流促進
 - (6) 日仏海洋、水産学者の相互の親睦のために集会を開くこと
 - (7) 会報の発行および出版
 - (8) その他本会の目的を達するために必要な事業
- 第4条 本会には、海洋、水産学の分野に応じて分科会を設けることができる。
分科会は評議員会の決議によって作るものとする。
- 第5条 本会の事務所は日仏会館（〒150 東京都渋谷区恵比寿3丁目9番25号）に置く。
- 第6条 本会に地方支部を置くことができる。
- 第7条 本会会員は本会の目的に賛成し、所定の会費を納めるものとする。
会員は正会員、学生会員および賛助会員とする。
- 第8条 正会員会費は年額6,000円、学生会員会費は年額4,000円、賛助会員会費は一口年額10,000円とする。
- 第9条 本会は評議員会によって運営される。
評議員の定数は50名とし、正会員の投票によって選出される。選挙事務は別に定める選出規定による。
会長は評議員会の同意を得て5名までの評議員を追加することができる。
- 評議員の任期は2年とする。ただし、重任を妨げない。
- 第10条 評議員はその内より次の役員を選ぶ。ただし、監事は評議員以外からも選ぶことができる。
会長 1名、副会長 2名、幹事 10名、監事 2名
役員任期は2年とする。ただし、重任を妨げない。
役員の選出方法は別に定める選出規定による。
- 第11条 本会に名誉会長、顧問および名誉会員を置くことができる。名誉会長、顧問および名誉会員は評議員会の決議により会長これを委嘱または推薦する。
日仏会館フランス人学長を本会の名誉会長に推薦する。
- 第12条 会長は本会を代表し、総会および評議員会の議長となる。会長事故あるときは副会長がこれに代わる。
会長、副会長および幹事は幹事会を構成し、本会の庶務、会計、編集、研究発表、渉外などの会務を行う。
監事は本会の会計を監督する。
- 第13条 年に1回総会を開く。総会では評議員会の報告を開き、会の重要問題を審議する。会員は委任状または通信によって決議に参加することができる。
会長は必要に応じて評議員会の決議を経て臨時総会を招集することができる。
- 第14条 本会則の変更は総会の決議による。

日仏海洋学会評議員・役員選出規定

1. 本規定は日仏海洋学会会則第9条および第10条に基づき本会の評議員および役員の選出方法について規定するものである。
2. 評議員は正会員の50名連記無記名投票により選出する。
評議員の選挙事務は庶務幹事が行う。ただし、開票にあたっては本会役員以外の会員2名に立会人を委嘱するものとする。
3. 会長は評議員の単記無記名投票により選出する。
会員選挙の事務は庶務幹事が行う。ただし、開票にあたっては本会役員以外の会員2名に立会人を委嘱するものとする。
4. 副会長、幹事、および監事は、会長の推薦に基づき評議員会で決定する。
5. 本規定の改正は評議員会の議を経て行う。

日仏海洋学会賞規定

1. 日仏海洋学会賞（以下「学会賞」という）を本学会に設ける。学会賞は本学会員で、原則として本学会誌に発表した論文の中で、海洋学および水産学において顕著な学術業績を挙げた者の中から、以下に述べる選考を経て選ばれた者に授ける。
2. 学会賞受賞候補者を選考するため学会賞受賞候補者推薦委員会（以下「委員会」という）を設ける。
3. 委員会の委員は13名とする。
委員は毎年春の評議員会で選出し、委員長は委員の互選により定める。
会長は委員会が必要と認めた場合、評議員会の同意を得て2名まで委員を追加委嘱することができる。
4. 委員会は受賞候補1件を選び、12月末までに選定理由をつけて会長に報告する。
5. 会長は委員会が推薦した候補者につき無記名投票の形式により評議員会にはかる。投票数は評議員総数の3分の2以上を必要とし、有効投票のうち4分の3以上の賛成がある場合、これを受賞者として決定する。
6. 授賞式は翌年春の学会総会において行い、賞状、メダルおよび賞金を贈呈する。賞金は5万円とする。
7. 本規定の改正は評議員会の議を経て行う。

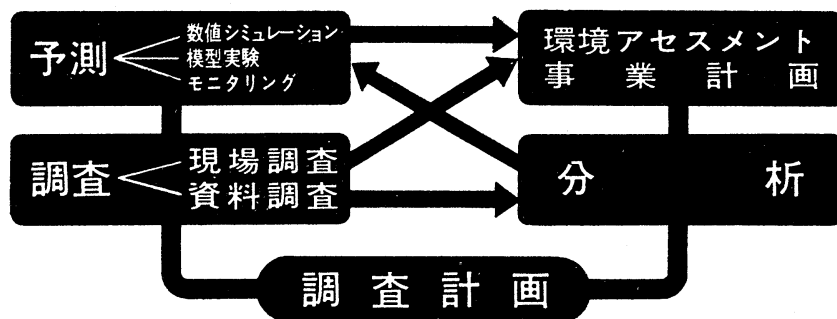
覚 書

1. 委員は各専門分野から選出されるよう十分配慮すること。
2. 受賞者は原則として順次各専門分野にわたるよう十分配慮すること。

賛 助 会 員

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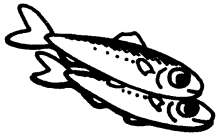
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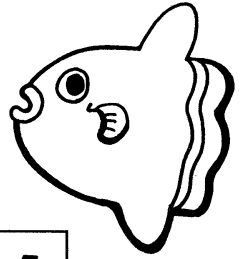


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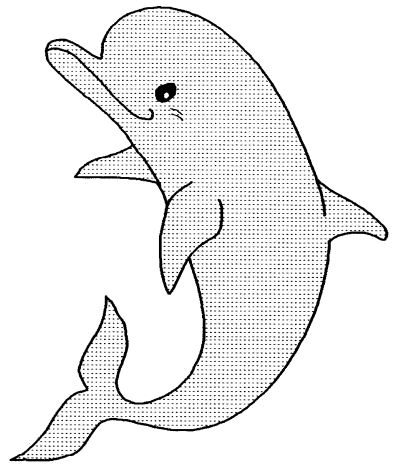
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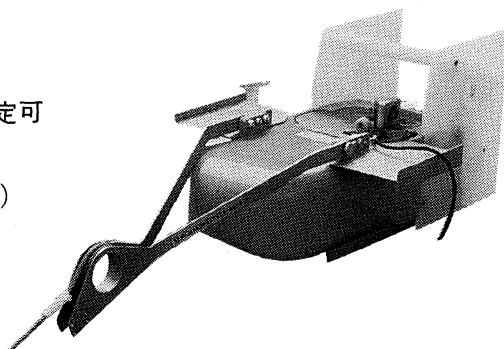
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日仏海洋学会入会申込書

(正会員・学生会員)

	年度より入会	年 月 日申込
氏 名		
ローマ字		年 月 日生
住所 〒		
勤務先 機関名		
電 話		
自宅住所 〒		
電 話		
紹介会員氏名		
送付金額	円	送金方法
会誌の送り先 (希望する方に○をつける)	勤務先	自宅

(以下は学会事務局用)

受付	名簿 原簿	会費 原簿	あて名 カード	学会 記事
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入会申込書送付先: 〒150 東京都渋谷区恵比寿3-9-25

(財)日仏会館内

日 仏 海 洋 学 会

郵便振替番号: 00150-7-96503

日 仏 海 洋 学 会 編 集 委 員 会 (1996-1997)

委員 長: 山口征矢

委 員: 青木三郎, 半沢正男, 堀越増興, 前田 勝, 落合正宏, 松山優治, 柳 哲雄, 渡辺精一

海外委員: H. J. CECCALDI (フランス), E. D. GOLDBERG (アメリカ), T. ICHIYE (アメリカ), T. R. PARSONS (カナダ)

幹 事: 落合正宏, 佐藤博雄

投 稿 の 手 引

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2. 原稿は海洋学および水産学両分野の原著論文, 原著短報, 総説, 書評, 資料などとする。すべての投稿は, 本文, 原図とも正副2通とする。副本は複写でよい。本文原稿用紙はすべてA4判とし, 400字詰原稿用紙(和文)に, または厚手白紙にダブル・スペース(和文ワープロでは相当間隔)で記入する。表原稿および図説明原稿は, それぞれ本文原稿とは別紙とする。
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