La mer 46 : 29-36, 2008
Société franco-japonaise d'océanographie, Tokyo

Dinophysis (Dinophyceae) in the pelagic waters of central and western Pacific

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Abstract: *Dinophysis* species were observed in the pelagic waters of central and western Pacific. A total of 33 species, including many rare species that have been seldomly seen before, were recorded. Two species, *D. acutissima* and *D. balechii,* were confirmed for the occurrence for the first time since their first descriptions. Compared to the original descriptions, specimens found in the region usually showed some levels of morphological variations. *D. doryphorum, D. hastata, D. parvula* and *D. schuettii* each comprised more than one morphotypes, the conspecificity of which is uncertain. These uncertainties call for further studies on both morphology and genetics of the genus.

Keywords: *Dinophysis, morphology, morphotype, western and central Pacific*

1. Introduction

EHRENBERG described the genus *Dinophysis* in 1839 with *D. acutata* as the type species. It was the only genus of dinophysoids until 1883, when STEIN introduced several other genera, including the morphologically closely related genus *Phalacroma.* The basic criteria for separation of *Dinophysis* and *Phalacroma* are the height of epitheca and the inclination of the cingular list. Species with low epitheca (which is not detectable above the cingular list) and anteriorly–inclined cingular list are classified as *Dinophysis*, while those with detectable epitheca and horizontal cingular list are classified as *Phalacroma.* However, since there are many intermediate species, the delineation between the two genera is not clear and the generic assignments by taxonomists were, as KOFOID and SKOGSBERG (1928) stated, "arbitrary". Considering the problem, ABÉ (1967) and BALECH (1967) independently proposed to merge genus *Phalacroma* to *Dinophysis*. Thereafter, although there are still sporadically taxonomists such as STEIDINGER (1997) and HALLEGRAEFF (2002) keeping the two genera separated, this merging is generally accepted by taxonomists (PARKE and DIXON, 1968; LARSEN and MOESTRUP, 1992; TAYLOR *et al.* 2003 e.g.).

So far, more than 200 species of *Dinophysis* were reported world wide (SOURNIA, 1968). *Dinophysis* are well documented in many parts of the world such as the Atlantic (STEIN, 1883; MURRAY and WHITTING, 1899; SCHÜTT 1895, JÖRGENSEN, 1923 and NORRIS and BERNER, 1970), the Indian Ocean (TAYLOR, 1976). In the Pacific region, however, studies on this genus are limited to the eastern waters (KOFOID and SKOGSBERG 1928) and the neritic western waters (OKAMURA 1907, 1912; BÖHM, 1936; WOOD 1954; ABÉ, 1967). The pelagic waters of central and western Pacific remain poorly understood.

This study tries to grasp the *Dinophysis* species composition in these poorly known areas.

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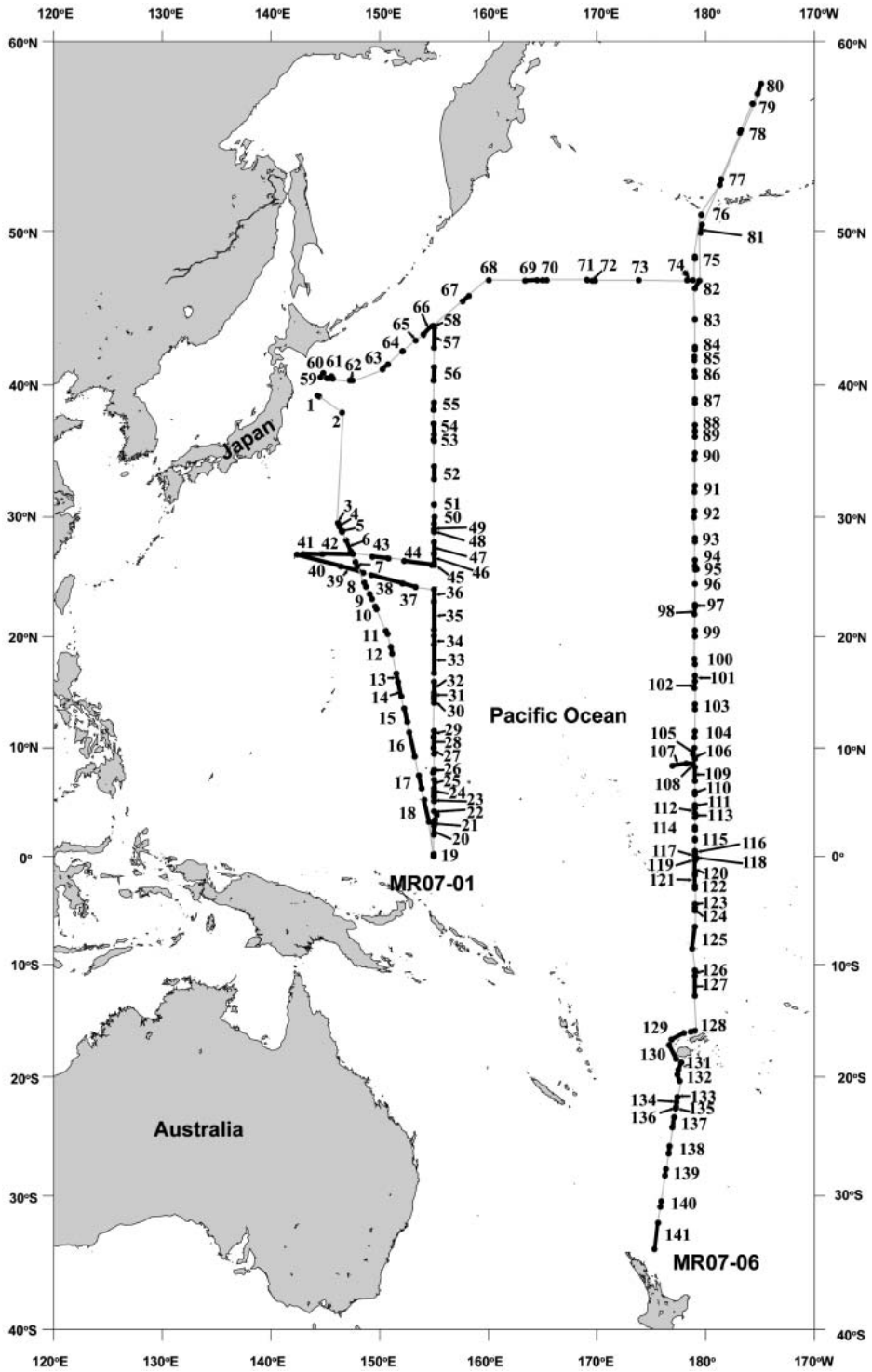


Fig. 1. Map showing the sampling stations during MR07–01 and MR07–06 cruises to the central and western Pacific Ocean. Numbers indicate station numbers.

2. Materials and methods

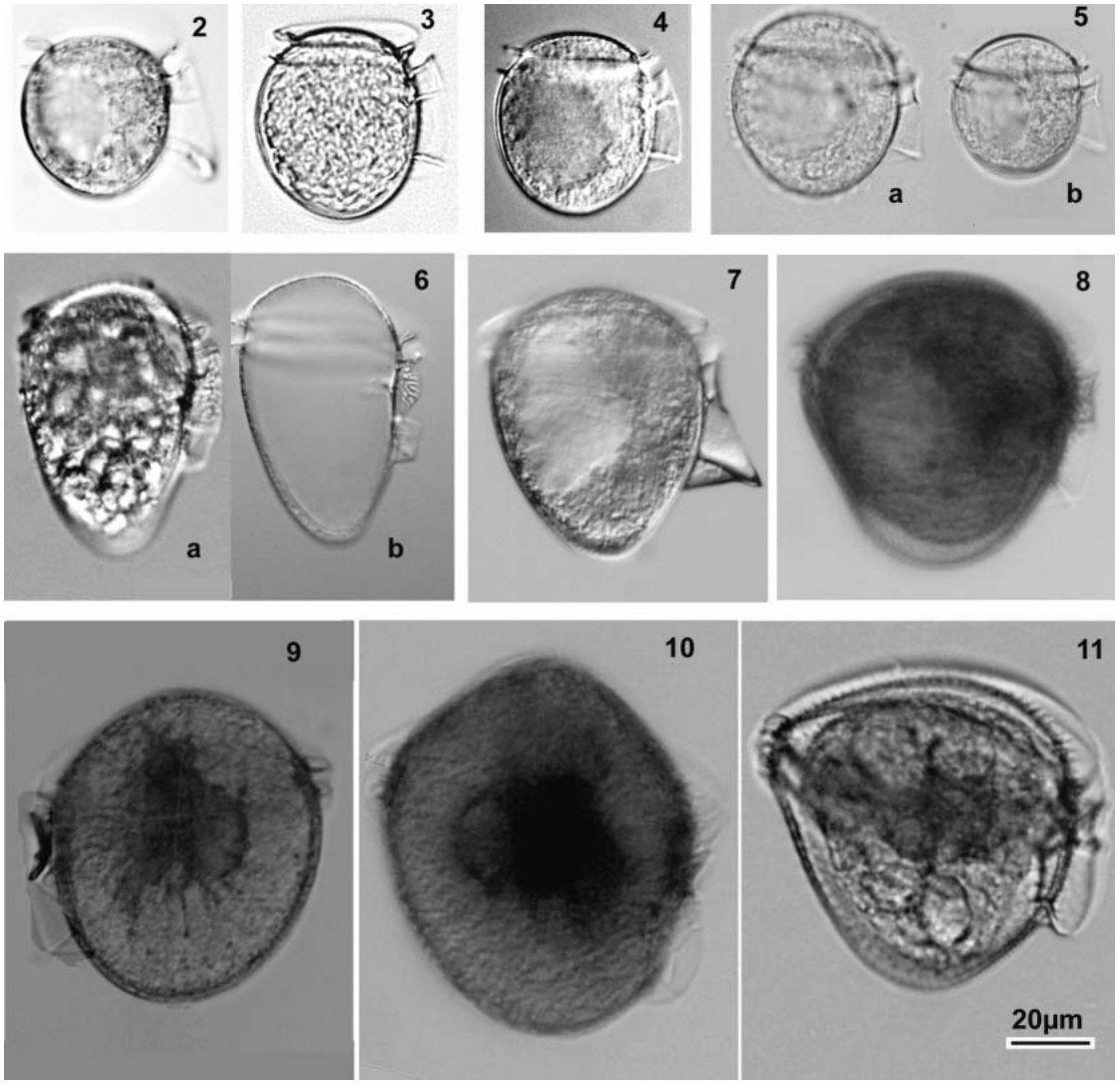
The study was based on materials collected during two cruises of R/V MIRAI, MR07–01 and MR07–06, in the Pacific Ocean (Fig. 1) during 16th February – 26th March 2007 and 8th October – 26th December 2007, respectively. Plankton samples (totally 141 samples) were collected by filtering the seawater, which was continuously pumped from the ship bottom (at depth of about 4.5 m) during cruising, through a plankton net with a mesh size of 20 μm. Live cells of *Dinophysis* were microscopically isolated using a capillary pipette before transferred to a chamber made of a vinyl frame and glass slide (following HORIGUCHI *et al.* 2000) and covered with a coverslip for detailed observation. Morphological characteristics were observed under an Olympus BX 60 microscope, at resolutions of 100 x to 400 x (sometimes 1000 x). Images of live cells were taken using a DP 25 Digital Camera accompanied by DP2–BSW software (Olympus). Identification of species was based on original descriptions. In cases where the original description was unclear or unavailable, the classification was based on the earliest taxonomical interpretation of the species or based on major taxonomical accounts of KOFOID and SKOGSBERG (1928), JÖRGENSEN (1923), ABÉ (1967) and TAYLOR (1976). Grouping of morphological groups was made following KOFOID and SKOGSBERG (1928)'s definitions.

3. Results

A total of thirty–three species of *Dinophysis*

Table 1. List of *Dinophysis* species found in the central and western Pacific during R/V cruises MR07–01 and MR07–06.

Morphological groups and species	Stations where the species was found
***Rotundatum* group**	
1. D. lativelata (KOFOID et SKOGSBERG) BALECH (fig. 2)	130
2. D. rotundata CLAPARÈDE et LACHMANN (fig. 3)	6,15,60,62,68,70,75,77,78,82,126,128, 130,142
3. D. whittingae BALECH (fig. 4)	54,56,50,60,62,69,70,75,77,78,82,84,128,130
4. D. parvula (SCHÜTT) BALECH (fig. 5 a-b)	12,27,29 30,32,33 38,40,85,84,86
***Argus* group**	
5. D. elongata (JÖRGENSEN) BALECH (fig. 6 a-b)	86,138
6. D. amandula SOURNIA (fig. 7)	5,15,16,17,20,24,35,40,77,82,90,91,96,105,124,126,130
7. D. acutoides Balech (fig. 8)	27,38
8. D. argus (STEIN) ABÄ (fig. 9)	35,40,136
9. D. apicata (KOFOID et SKOGSBERG) ABÉ (fig. 10)	15,17,18,24,35,38,53,91,92
***Cuneus* group**	
10. D. cuneus (SCHÜTT) ABÄ (fig. 11)	17,24,33,36,53,91,92,102,104,126 127,130,137
***Rapa* group**	
11. D. rapa (STEIN) BALECH (fig. 12)	15,16,17,19,20,24,27,30,89,92,96,97,99
12. D. mitra (SCHÜTT) ABÉ (fig. 13)	15,16,60,62,91,92,93,96,97,99,105,124,126,134,141
13. D. favus (KOFOID et MICHENER) ABÉ (fig. 14)	18,20
14. D. hindmarchii (MURRAY et WHITTING) BALECH (fig. 15)	95,99,126,135,136
***Doryphorum* group**	
15. D. cf. cuneolus (KOFOID et SKOGSBERG) BALECH (fig. 16)	95
16. D. cf. pugiunculus (JÖRGENSEN) BALECH (fig. 17)	130,137
17. D. doryphorum (STEIN) BALECH (fig. 18)	4,7,16,17,18,20,24,38,88,89,91,92,93,102,120,124,130,134,136,141
18. D. acutissima GAARDER (fig. 19)	86
***Hastata* group**	
19. D. hastata STEIN *sensu lato* KOFOID et SKOGSBERG (fig. 20a-c)	7,22,23,24,30,34,35,40,96,99,100,102,105,116,122,124,128,130,131,133,137
20. D. schuettii MURRAY et WHITTING (fig. 21 a-b)	6,16,17,18,24,38,92,100,102,126,128,130
21. D. pusilla JÖRGENSEN (fig. 22 a-b)	40,96,130,136
22. D. balechii NORRIS et BERNER (fig. 23 a-b)	20,85,86,126,128
***Acuta* group**	
23. D. exigua KOFOID et SKOGSBERG (fig. 24)	20,34,35,89,40
24. D. infundibulus SCHILLER *sensu* ABÉ (fig. 25)	69,77
25. D. similis KOFOID et SKOGSBERG (fig. 26)	17,25,30,40,90,91,100,114,130
26. D. norvegica CLAPARÈDE et LACHMANN (fig. 27a-b)	69,70,71,72,74,75,76,77,78,81,82
27. D. recurva KOFOID et SKOGSBERG (fig. 28)	40,69,70,71,72,73,74,75,76,77,82
28. D. cf. ovum SCHÜTT (fig. 29)	88
29. D. fortii PAVILLARD (fig. 30)	5, 69,87,88,91
30. D. schroederi PAVILLARD (fig. 31)	40,41,43,44,45,50,53,62,88,133,141
***Caudata* group**	
31. D. caudata SAVILLE-KENT (fig. 32)	38,43,45,50,51,53,54,60,61,62,63
32. D. tripos GOURRET (fig. 33)	45,50,53,54,56,60,62,69,82,83,84,85,86,92,108
***Expulsa* group**	
33. D. expulsa KOFOID et MICHENER (fig. 34)	10,90,93,121

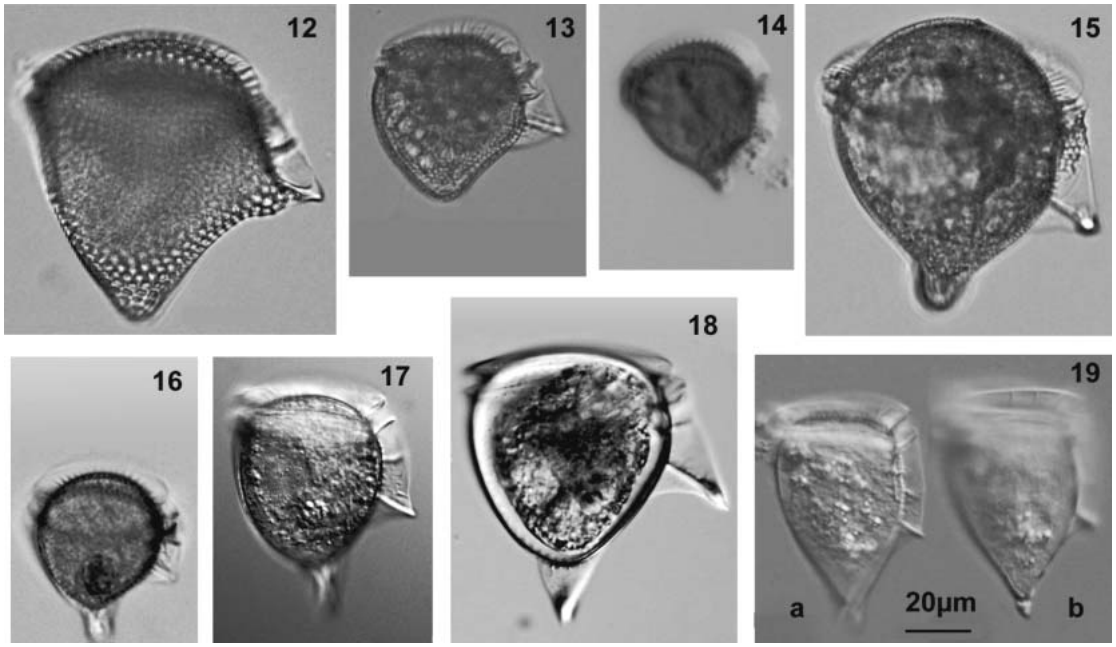


Figs. 2–11. *Dinophysis* of the *rotundata, argus* and *cuneus* groups. 2–5 : the *rotundata* group. 2. *D. lativelata,* 3. *D. rotundata,* 4. *D. whittingae,* 5. *D. parvula.* 6–10 : the argus group. 6. *D. elongata,* 7. *D. amandula.* 8. *D. acutoides,* 9 - *D. argus,* 10- *D. apicata.* 11 : the cuneus group : 11. *D. cuneus.* Scale bar is applied for all figures.

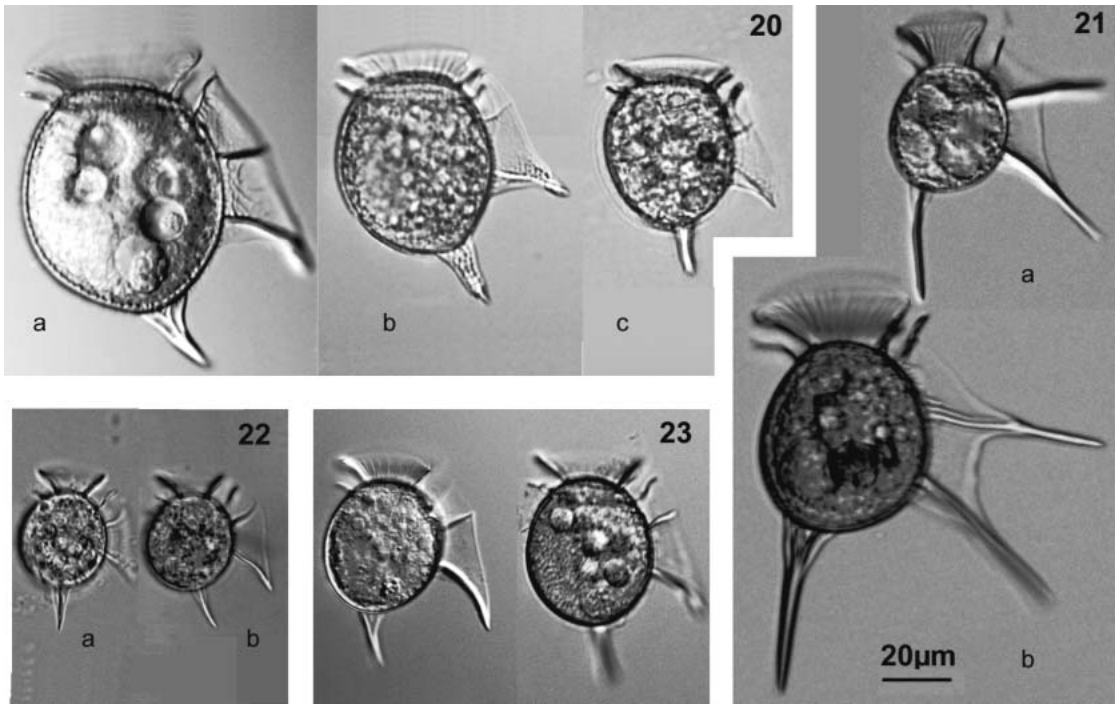
belonging to nine morphological groups were recorded (table 1). Images of live–specimen of these species are shown in Figures 2–34. Among them, fifteen species were widely distributed (recorded in more than ten stations – see table 1); nine species had very limited distribution (found in only one or two stations); and the rest nine species were moderately distributed (found in three to ten stations). Particularly, the two species, *D.* cf. *cuneolus* (Fig. 15) and *D. acutissima* (Fig. 19) were so rare that, for each species, we were able to find only one cell during the two cruises.

In addition to these thirty–three species, we also encountered some new species. Descriptions of these species are being prepared.

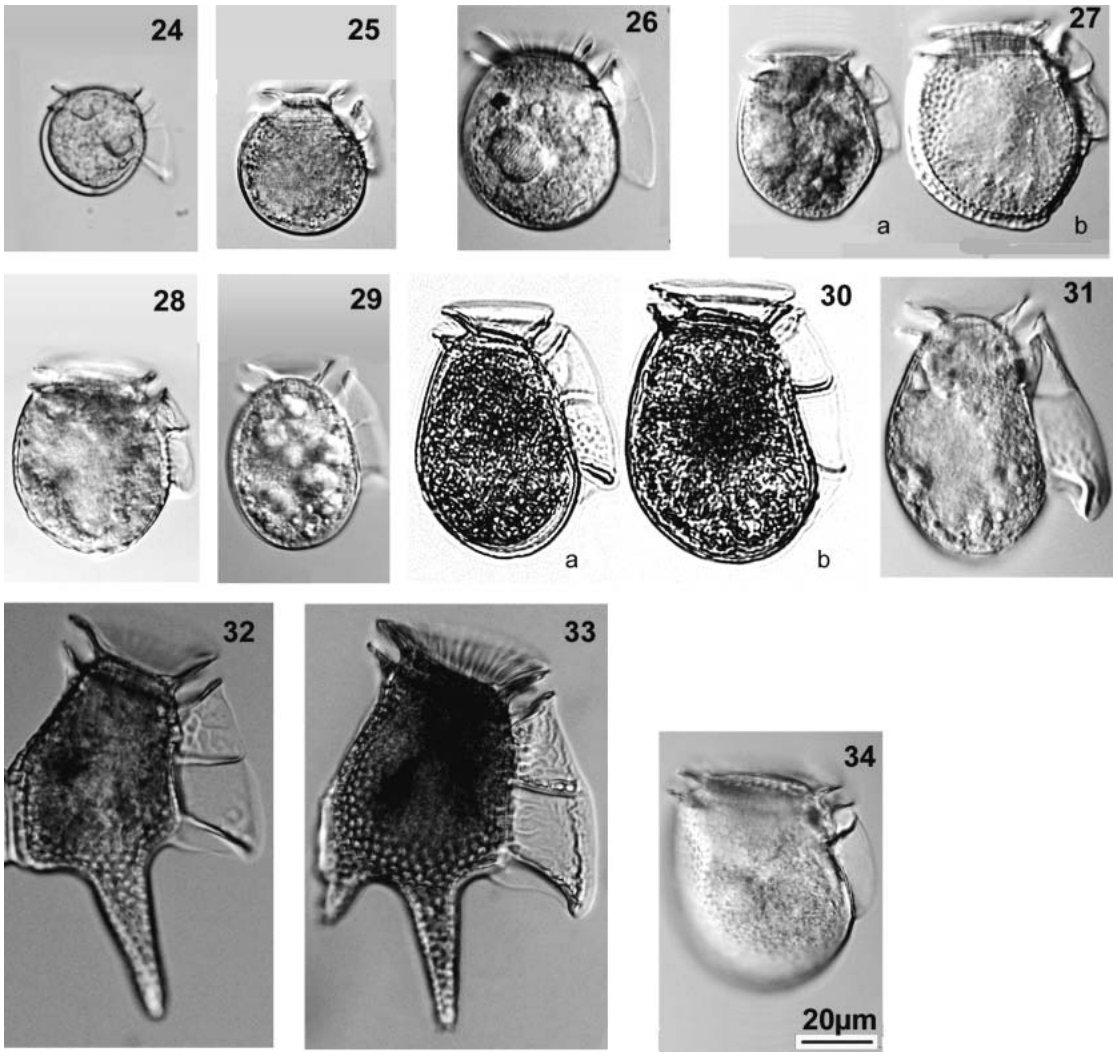
In terms of morphology, most of *Dinophysis* species found in the region showed some levels of variation from their type description. Four species, *D. doryphorum* (Fig. 18), *D. hastata* (Fig. 20), *D. parvula* (Fig. 5) and *D. schuettii* (Fig. 21), each showed several morphotypes,



Figs. 12–19. *Dinophysis* of the *rapa* and *doryphorum* groups. 12–15：*rapa* group. 12. *D. rapa,* 13. *D. mitra,* 14. *D. favus,* 15. *D. hindmarchii.* 16–19：*doryphorum* group. 16. *D. cf. cuneolus,* 17- *D. cf. pugiunculus,* 18- *D. doryphorum,* 19- *D. acutissima.* Scale bar is applied for all figures.



Figs. 20–23. *Dinophysis* of the *hastata* group. 20. *D. hastata,* 21. *D. schuettii,* 22. *D. pusilla,* 23. *D. balechii.* Scale bar is applied for all figures.



Figs. 24–34. *Dinophysis* of the *acuta, caudata* and *expulsa* groups. 24–31 : the *acuta* group. 24. *Dinophysis exigua,* 25. *D. infundibulus,* 26. *D. similis,* 27. *D. norvegica,* 28. *D. recurva,* 29. *D. ovum,* 30. *D. fortii,* 31. *D. schroederi.* 32–33 : the *caudata* group. 32. *D. caudata,* 33. *D. tripos.* 34 : the *expulsa* group. 34 : *D. expulsa.* Scale bar is applied for all figures.

some of which may not be conspecific. These morphotypes are being subjected to further morphological and molecular analysis (NGUYEN *et al.*, in preparation).

4. Discussion

Prior to this study, there have been only few studies on *Dinophysis* in the central and western Pacific, although numerous studies on phytoplankton have been carried out in the region (see HASEL (1960) for the list). Except four species, *D. hastata, D. schuettii, D. similis* (Fig. 26), and *D. caudata* (Fig. 32), which have been reported from the tropical water of middle Pacific by RAMPI (1952) and SCHRÖDER (1906), the rest twenty–nine species are new records for the region.

Most of these *Dinophysis* species (thirty out of thirty–three species), however, have been previously reported elsewhere in Pacific Ocean, either in the pelagic eastern Pacific (KOFOID and SKOGSBERG, 1928) or the neretic waters of

Australia (WOOD, 1954), Japan (OKAMURA 1907, 1912 and ABÉ, 1967) and South China Sea (BÖHM, 1936).

Three species, *D. acutissima, D. balechii* (Fig. 23) and *D. pussila* (Fig. 22), were for the first time recorded in the Pacific Ocean. Particularly, for *D. acutissima* and *D. balechii*, this is the first confirmation of their existence since their first descriptions were made by GAARDER (1954) and NORRIS and BERNER (1970), respectively.

It should be noted that three species *D. recurva, D. whittingae* and *D. amandula* are frequently documented under invalid names *D. lenticula, D. rudgei* and *D. ovum*, respectively in some papers such as ABÉ (1967), GÁRATE – LIZÁRRAGA *et al.* (2007).

The first species, *D. recurva*, was first described by Pavillard (1916) under the name *D. lenticula*. KOFOID and SKOGSBERG (1928) (page 228) renamed it as *D. recurva* since they recognized that the name *D. lenticula* had been preoccupied. ABÉ (1967) used the name *D. lenticula* to refer this species, perhaps, because of overlooking KOFOID and SKOGSBERG' S argument.

The second species, *D. whittingae*, was named by BALECH (1967) for the senior synonym *Phalacroma rudgei* when he merged the genus *Phalacroma* to *Dinophysis*. In the same year, ABÉ (1967) made the same merging but this author used the name *D. rudgei* for *P. rudgei* without recognizing that the name *D. rudgei* had been previously reserved for another species by MURRAY and WHITTING (1899).

The third species, *D. amandula*, passed a complicated history of systematic. It was originally described by SCHÜTT (1895) under the name *Phalacroma ovum* (In his figure (figure 112, plate 2), however, it was noted by the name *P. operculoides*; but this was a mistake – see KOFOID & SKOGSBERG, 1928, page 121 for explanation). When merging genus *Phalacroma* to *Dinophysis*, BALECH (1967) renamed it as *D. amygdala* because the name *D. ovum* was preoccupied (*D. ovum* SCHÜTT, 1895). Later, however, SOURNIA (1973) found that *D. amygdala* was invalid because it was a homonym for *D. amygdalus*, a species raised by PAULSEN (1949). SOURNIA therefore again renamed it as *D. amandula*.

Ackowledgements

We would like to express our sincere thanks to Mr. Kazu MATSTUMOTO of Japan Agency for Marine–Earth Science and Technology who provided us the opportunity to cruise on M/V Mirai during the MR07–01 and MR07–06 cruises. We deeply thank the two reviewers for their valuable constructive comments. Dr. Yukio NAGAHAMA and Ms. Dao Viet HA gave useful discussions on the content of the manuscript. Mr. Takuhei SHIOZAKI gave helps in plotting precisely the sampling positions on map. Ms. Leni YAP–DEJETO helped with the English check.

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Received June 17, 2008
Accepted August 20, 2008