

## 한국연안해역 외편모조류 시스트 연구에 관한 고찰

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### Summary on the Dinoflagellate Cyst Assemblages of Modern Sediments from Korean Coastal Waters and Adjoining Sea

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**Abstract** - To investigate the research state and characteristics of dinoflagellate cyst along the Korean coastal waters, this work analyzed 45 studies conducted in the Korean coasts and basin, the south of Jeju, East China Sea including some part of the Yellow Sea. It was found that the research on dinoflagellate cyst began in the later half of the 1980s in Korea, and that the research areas focused on eutrophied regions where a red tide occurred or on the seas where coastal development occurred. In other words, no research on the East Sea was found. In terms of research contents, there were various studies on analysis of cyst assemblage, tracking of the changes in marine environment like process of eutrophication, roles as a seed population in occurrence of a red tide, creation of cyst by use of sediment trap and tracking of its changes, morphological changes by the change of pH concentration in the hypoxia zone of eutrophied region, germination of a specific species, and other international-level studies. Species composition and cell density also varied in the Korean coastal waters. However, much research on dinoflagellate cyst in Korea is not systematic, and is fragmentary and individual and hence suffers from great limitations. The research results so far have focused only on specific regions, and sporadic research had been conducted by specific research groups. Dinoflagellate cyst of surface sediments represents the accumulation index of pelagic environment in the sea and is a useful index to understand the marine environment efficiently. In conclusion, Korea requires organized human resources and collaborative research on dinoflagellate cyst which in turn should be considered as a component of marine ecosystem and as an essential aspect of marine biology.

**Key words** : dinoflagellate, cyst assemblage, modern sediments, Korean coastal waters, motile cells

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## 서 론

외편모조류는 단세포의 생물로서 해양의 기초생산자에서 규조류 다음으로 중요한 위치를 차지하는 분류군으로 현재 약 2,500종이 알려진다(Taylor *et al.* 2008; Hoppenrath *et al.* 2009). 단세포 생물의 일반적인 번식은 핵분열에 의한 무성생식을 기본으로 한다. 외편모조류의 유영세포 역시 무성생식으로 성장하지만, 서식환경이 나빠지면 배우자의 접합으로 유성생식으로 변화한다. 유영세포의 배우자 접합으로 일시적으로는 두 개의 종편모를 가지는 운동성 접합자(planozygote)가 되지만, 얼마 없어 내부에 휴면성 접합자(hypnozygote, resting spore, resting cyst)를 만들어 운동성 접합자의 세포벽 대신에 내구성의 강한 유기물 세포벽을 만들어 운동성 상실은 물론 유영세포와는 형태를 달리하는 휴면포자(resting cyst)가 되어 해저 표층퇴적층에 침강하여 휴면상태에 들어간다. 이와 같은 휴면상태의 세포를 일반적으로 시스트(cyst)라고 불리고 있다. 휴면포자는 몇 주에서 몇 개월을 해저 표층퇴적층에서 휴면한 다음, 수온 등 외부의 환경 자극에 의해 재차 발아하여 두 개의 종편모를 가지는 운동성 감수모세포(planomeiocyte)로 표영 환경으로 돌아와 무성생식에 의한 유영세포 시기를 보낸다. 다만 아직까지 외편모조류의 많은 종에 대해 휴면포자를 포함한 생활사가 분명하게 밝혀져 있지 않다(Matsuoka 1999). 현재 유영세포로 발견되는 외편모조류의 약 10~20% 정도가 생활사에서 유성생식에 의한 시스트를 만드는 것으로 추정되고 있다(Head 1996; Price and Pospelova 2011; Bonnet *et al.* 2012).

외편모조류가 휴면기 세포인 시스트를 만드는 이유는 수권 생태계에서 군집의 생존율을 높이기 위한 전략(Odebrecht 1982; Dale 1983; Walker 1984; Sarjeant *et al.* 1987; Heiskanen 1993)임과 동시에 유영세포의 군집을 확산시키거나 유전자의 재조합을 위한 생존전략이라 할 수 있다(Anderson 1984; Sarjeant *et al.* 1987; Matsuoka *et al.* 2010). 이와 같은 시스트의 형성과 발아에 영향을 주는 인자로는 수온, 질소와 인 등 영양염류, 광량, 염분, 미량금속 원소, 용존산소, 황화수소, 극지방의 얼음 피도와 같은 다양한 무생물 환경과 세균이나 기초생산과 같은 생물학적 환경 등이 알려진다(Bibby and Dodge 1972; Anderson *et al.* 1987; Ellegaard *et al.* 1998; Kremp and Anderson 2000; Sgrosso *et al.* 2001; Yoo and Shin 2004; Matrai *et al.* 2005; Figueroa *et al.* 2011; Candel *et al.* 2012 etc).

외편모조류 시스트의 생리·생태학적 특성으로 현생

표층퇴적물의 시스트 연구는 약 50년 정도의 짧은 역사임도 불구하고, 외편모조류의 생활사 규명을 위한 생태학적 연구(van Stosch 1973; Walker and Steidinger 1979; Morey-Gains and Ruse 1980; Anderson *et al.* 1983; Kita *et al.* 1993; Uchida *et al.* 1996; Kim and Han 2000; Anderson and Rengefors 2006; Alpermann *et al.* 2009; Bravo *et al.* 2012 etc)는 물론, 해수유동, 전선, 용승, 유빙과 수리 등의 물리학적 현상 파악을 위한 생물학적 증거자료와 무산소 수괴나 수질 환경의 지시종 등 해양현상의 이해(Wall *et al.* 1977; Tyler *et al.* 1982; Anderson and Keafer 1987; Nehring 1997; Devillers and de Vernal 2000; Gu *et al.* 2003; Yoo and Shin 2004; Sorrel *et al.* 2006; Solignac *et al.* 2008; Elshanawany *et al.* 2010; de Vernal and Rochon 2011; Bonnet *et al.* 2012 etc), 그리고 매년 같은 시기에 동일 장소에서 유독/유해성 외편모조류에 의한 적조 발생의 종자군(seed population) 역할과 유독/유해 외편모조류의 분포도 작성, 산업활동의 결과로 발생하는 연안/내만해역의 부영양화 등 환경변화의 추적자로서도 유용한 연구 수단으로 이용된다(Steidinger 1975; Anderson and Keafer 1987; Kim *et al.* 1990; Dale *et al.* 1999; Matsuoka 1999, 2001, 2011; Dale 2000, 2001a, b, 2009; Klemp and Anderson 2000; Joyce *et al.* 2002; Joyce and Pitcher 2004; Wang *et al.* 2007; Smayda 2008; Shin *et al.* 2010b; Matsuyama 2012; Usup *et al.* 2012; Satta *et al.* 2013 etc). 또한 선박 균형수(ballast water) 등에 의한 유독외편모조류 등 중의 확산과 외래종의 도입(Hallegraeff *et al.* 1990; Hallegraeff and Bolch 1992; Ichikawa *et al.* 1992; Hamer *et al.* 2001; Hong *et al.* 2003; Patil *et al.* 2005; Pertola *et al.* 2006; Bolch and de Salas 2007; Fahnenstiel *et al.* 2009; Dai *et al.* 2012 etc)과 고환경을 포함한 기후 변화를 해석하는 수단으로도 유용하게 이용되며(Chalson *et al.* 1987; Edwards *et al.* 1991; Wall *et al.* 1977; Kunz-Pirrung *et al.* 2001; Pospelova *et al.* 2006; Grøfjeld *et al.* 2009; Guiot and de Vernal 2011; Naidu *et al.* 2012; Price *et al.* in press etc), 생물진화 및 생존전략, 어패류의 독화에 의한 공중 보건 위생의 위협, 상위 영양단계 생물의 섭식행동, 먹이사슬을 통한 중의 재확산은 물론 생태계 및 해양공간에서의 물질 수송 등의 분야(Wall and Dale 1968; Dale *et al.* 1978; Anderson 1984; Takeuchi 1985; Hallegraeff *et al.* 1989; Han *et al.* 1992; Corrales and Maclean 1995; Nehring, 1996; Anderson 1998; Persson 2000; Harper *et al.* 2002; Kremp *et al.* 2003; Lan *et al.* 2004; Bazzoni *et al.* 2006; Hoppenrath and Leander 2007; Cox *et al.* 2008; Persson and Smith 2009a, b; Anderson *et al.* 2012; Satta *et al.* 2013 etc) 및 생물지리 분포(Marret and Zonn-

evelde 2003; Zonneveld *et al.* 2013) 등 다양한 분야에서 연구의 대상으로 이용된다.

국내에서 와편모조류 시스트에 대한 연구는 1980년대 초 내만 해역에서 적조발생과 관련하여 시도된 연구보고(Kim *et al.* 1990; Lee and Yoo 1991; Moon *et al.* 1993)를 시초로 하여, 최근 다양한 연구가 수행되고 있지만, 매우 편향된 연구에 지금까지의 연구 내용을 정리한 내용이 없다. 따라서 국내의 와편모조류 시스트 연구의 실태와 특성에 대하여 정리하여, 앞으로 와편모조류 시스

트 연구를 수행하고자 하는 연구자들에게 도움을 주고자 본고를 정리한다.

## 재료 및 방법

한국 연안 해역의 와편모조류 시스트 연구 현황과 특성을 분석하기 위해 제공한 자료는 2013년 8월까지 국내·외의 전문학술지와 전문도서로 발간된 것만을 대상

**Table 1.** The list of studies on the dinoflagellate cysts in Korean coastal water (KCW)

Author and publication year	Study Area or Organisms	Remarks
Kim <i>et al.</i> 1990	eastern South Sea	
Kim 1991	Jinhae-Masan bay	Symposium
Lee and Yoo 1991	Jinhae-Masan bay	
Moon <i>et al.</i> 1993	Jinhae-Masan bay	
Kim 1994	Jinhae bay/ <i>Alexandrium</i> sp./germination	
Kim 1995	Jinhae bay/ <i>Alexandrium</i> sp./toxin profiles	
Lee and Matsuoka 1996	Jinhae-Masan bay, central South Sea	Symposium/book
Lee <i>et al.</i> 1998	Jinhae-Masan bay	
Kang <i>et al.</i> 1999	Tongyeong coasts	
Lee <i>et al.</i> 1999	Gamak bay	
Kim and Han 2000	Yeongil bay/ <i>Scrippsiella trochoidea</i> /germination	
Cho and Matsuoka 2001	East China Sea & Yellow Sea	
Cho <i>et al.</i> 2001	East China Sea	
Kim <i>et al.</i> 2002	regeneration/ <i>Cochlodinium polykrooides</i>	
Kim <i>et al.</i> 2002	germination/ <i>Alexandrium tamarense</i>	
Cho and Matsuoka 2003	East China Sea	
Cho <i>et al.</i> 2003	central South Sea	
Kim <i>et al.</i> 2003a	Gwangyang bay	
Kim <i>et al.</i> 2003b	Gwangyang bay	
Park and Yoon 2003	Gamak bay	
Cho <i>et al.</i> 2004	Jeju coasts and East China Sea	
Park <i>et al.</i> 2004	Gamak bay	
Park <i>et al.</i> 2004	germination/ <i>Alexandrium tamarense</i>	
Park <i>et al.</i> 2004	Seamangeum coasts	
Yoo and Shin 2004	germination/ <i>Alexandrium catenella</i> /tamarense, <i>Gymnodinium catenatum</i>	
Kim <i>et al.</i> 2005	Busan harbor	
Park <i>et al.</i> 2005	central South Sea	
Kim <i>et al.</i> 2007	life cycle/ <i>Cochlodinium polykrooides</i>	
Shin <i>et al.</i> 2007	western South Sea	
Shin <i>et al.</i> 2007	Geoje coast	
Kang <i>et al.</i> 2008	Methodology	
Park <i>et al.</i> 2008	western South Sea	Dominant species
Shin <i>et al.</i> 2008	Gamak bay/ <i>Alexandrium tamarense</i>	
Hwang <i>et al.</i> 2009	Yellow Sea	
Kim 2009	life cycle/ <i>Cochlodinium polykrooides</i>	
Kim <i>et al.</i> 2009	Gwangyang bay	
Park <i>et al.</i> 2009	life cycle/ <i>Cryptoperidiniopsis brodyi</i>	Foreign strain
Kim <i>et al.</i> 2010	East China Sea	
Pospelova and Kim 2010	Tongyeong coasts	
Shin <i>et al.</i> 2010	Gamak bay	
Shin <i>et al.</i> 2010	Yeoja bay	
Park <i>et al.</i> 2011	Saemangeum, Tongyeong, Jinhae-Masan, Gamak bay	Book
Shin <i>et al.</i> 2011	Yeoja and Gamak bay, Bokdol-bada	
Shin <i>et al.</i> 2012	Gamak bay (sediment trap)	
Shin <i>et al.</i> 2013	Gamak bay/ <i>Scrippsiella trochoidea</i> /hypoxia	

으로 하였다. 와편모조류 시스트를 대상으로 하여 작성된 학위논문이나 연구보고서가 있지만, 이들은 분석 대상에서 제외하였다. 그리고 대상 해역은 한국의 내만과 연안 해역은 물론 제주도 남부해역을 포함하는 동중국해와 황해를 대상으로 국내 연구자가 참여하여 작성한 학술논문은 대상에 포함시켰다. 분석에 사용한 문헌을 발표년대 순으로 주된 연구내용과 함께 Table 1에 정리하였다. 국내 전문학회지 25편, 국제전문학회지 16편을 포함하여 45편의 문헌이다.

## 결과 및 고찰

### 1. 와편모조류 시스트의 연구변화와 특성

한국 연안 해역에서 수행된 와편모조류 시스트의 연구

는 1982년 한국 동남 연안 해역의 적조모니터링 정점의 표층퇴적물을 대상으로 한 것이 처음이다(Kim *et al.* 1990). 1982년 2월에서 11월까지 주간 또는 격주로 약 40개의 정점을 대상으로 분석하여 적조원인종이 되는 와편모조류 시스트 6종과 침편모조류 시스트 2종, 모두 8종의 시스트를 동정하고 있다. 이후 1980년대 진해만의 대규모 적조와 관련하여 표층퇴적물에 포함된 시스트 연구는 Lee and Yoo (1991)와 Moon *et al.* (1993) 등의 보고로 1990년대 전반은 진해만과 만산만을 중심으로 하는 극히 제한된 해역에서 출현종에 대한 연구가 수행되었다. 이와 함께 패류독화 원인종으로 알려진 유독 와편모조류인 *Alexandrium*의 발아와 독조성에 대한 연구가 있다(Kim 1994, 1995). 1990년대 후반에는 대상해역이 진해-마산만에서 통영연안해역과 가막만, 그리고 남해의 개방해역까지 확대되어, 시스트 출현종에 대한 연구가 수

**Table 2.** Study site and theme of the dinoflagellate cysts in KCW

Study site	Study items	Number of article	
East Sea	None	0	
West Sea	Seamangeum coasts	cyst assemblages	2 (1)
	Yellow Sea	cyst assemblages	2 (1)
South Sea	Busan harbor	cyst assemblages	1
	Jinhae-Masan bay	cyst assemblages	6 (1)
	Geojae coasts	cyst assemblages	1
	Tongyeong coasts	cyst assemblages	3 (1)
	eastern parts	blooming	1
	Gwangyang bay	cyst assemblages	3 (1)
		cyst assemblages and environmental analysis	2 (1)
	Gamak bay	cyst assemblages	4 (2)
		cyst assemblages and environmental analysis	2
		sediment trap	1
toxic plankton		1	
mophology variation with hypoxia		1	
Yeoja bay		cyst assemblages and environmental analysis	2 (1)
Bokdol-bada		cyst assemblages	1
western parts	cyst assemblages	2	
	central parts	cyst assemblages	4
East China Sea	cyst assemblages	3 (1)	
	cyst assemblages and environmental analysis	2	
Other regions and laboratory works	germination	5	
	life cycle	3	
	methodology	1	
	regeneration	1	
	toxic analysis	1	
Total		55 (10)	

( ) is indicate the number of duplication articles

행되었다(Lee and Matsuoka 1996; Lee *et al.* 1998, 1999; Kang *et al.* 1999). 2000년대에 들어 국내 와편모조류 시스트 연구는 활기를 띠게 되며, 연구 해역도 동해를 제외한 남해와 서해(황해) 일부해역, 그리고 동중국해까지 확대된다. 연구 내용도 출현종 파악에서 한 단계 진행된 발아 환경특성(Kim and Han 2000; Park *et al.* 2004; Yoo and Shin 2004), 생활사 파악(Kim *et al.* 2002, 2007; Kim 2009; Park *et al.* 2009), 주상 퇴적물 표본에 의한 부영양화 변화양상 파악 등 환경 변동 파악(Kim *et al.* 2003b; Park *et al.* 2004; Kim *et al.* 2009) 등으로 연구가 확대되었다. 그리고 최근인 2010년 이후는 양식장 등 특정 해역의 시스트 군집파악과 환경해석(Pospelova and Kim 2010; Shin *et al.* 2010), Sediment trap을 이용한 시스트 형성과 변화과정 추적(Shin *et al.* 2012), 그리고 빈/무산 소수역에서의 시스트의 형태 변화(Shin *et al.* 2013) 등 국제적 수준에 준하는 연구가 수행되고 있다.

그러나 2000년대 이후 활발한 와편모조류 시스트 연구에도 불구하고 시스트 연구는 적조와 해양개발 등 사회적 이벤트와 관련하여, 해역적으로는 남해안에 집중되어 있다(Table 2). 표에서 현재 동해를 대상으로 한 시스트 연구는 발아 실험을 위해 영일만에서 *Scrippsiella trochoidea* 종을 분리하기 위해 채집한 것(Kim and Han 2000)을 제외하면 전무한 실정이며, 분석 대상 45편의 문헌에서 복수 대상 해역을 중복 포함하더라도 황해를 포함한 서해안 4편, 제주도를 포함하는 동중국해 5편을 제외한 35편은 남해에 집중되어 있다. 특히 진해만, 광양만, 가막만 등 적조발생 또는 대규모 임해공업단지 조성에 따른 개발 사업이 이루어지는 남해 중앙부에서 동부해역에 편중된 경향을 나타낸다. 즉 현재 와편모조류 시스트의 연구는 다양한 분야에 응용되고 있고, 새롭게 그 영역을 확대하고 있으나, 국내의 여건은 아직도 제한된 연구 집단에 의해 산발적인 연구가 수행되고 있다고 할 수 있다.

## 2. 와편모조류 시스트의 출현종

현재 한국 연안 해역에 출현이 확인된 시스트 종은 1990년대 초반에는 10종 내외로 매우 제한적이었으나(Kim *et al.* 1990; Lee and Yoo 1991), 지금까지의 모두를 종합하면 약 90종으로 유영세포의 명칭을 기준으로 하면 61종에 달한다(Table 3). 이와 같이 유영세포와 시스트 기준에서 종 수 차이가 있는 것은 지구에 존재하는 생물군 중 유일하게 와편모조류의 연구에서 유영세포는 생물학자에 의해 시스트는 미고생물 영역인 지질학자에 의해 서로 독립적인 분류기준으로 연구가 수행되었기 때

문으로 동일 생물종에 대해 유영세포와 시스트가 각각 다른 종명을 사용하고 있기 때문이다. 이와 같은 현상은 국제식물명명규약에서 용납될 수 없지만, 유영세포의 생활사가 확인된 것은 전체 10% 내외로 시스트와 유영세포 사이의 대응관계가 충분하지 못한 것과 현재 멸종된 2,000여 종의 시스트에 대한 유영세포의 형태 파악은 불가능 하여 화석의 형태로 분류할 수밖에 없다는 두 가지 이유에서 당분간은 동일 종에 대한 두개의 분류체계는 양립될 수밖에 없을 것으로 판단되고 있다(Wall and Dale 1968; Dale 1983; Fensome *et al.* 1993; Matsuoka and Fukuyo 2000).

또한 와편모조류 유영세포는 갑작스런 담수 유입 등 외부 환경의 일시적인 변화에 대해서도 형태를 변화시켜 일시적으로 해저에 침강하였다가 회복되는 일시성 시스트(pellicle cyst, temporary or ecdysal cyst)를 형성하는 것은 잘 알려져 있다(Dale 1977; Walker 1984). 일시성 시스트에서는 운동성 접합자는 관찰되지 않는다. 와편모조류가 유독/유해성 적조원인생물과 표영 환경이 누적지표로 환경 분야 응용뿐만 아니라 독성 단백질 등 일부의 물질은 신약개발이나 기능성 물질 탐색이 중요한 대상이 되고 있어, 와편모조류가 중요 연구 대상 생물군이 되면서 다양한 유영세포에 대해 새로운 시스트의 보고가 매우 활발하다. 이런 과정에 현생 유영세포에 대해 기존의 보고된 많은 시스트에는 시스트가 아닌 일시성 시스트임을 지적하는 등(Bravo *et al.* 2010), 시스트 연구에 안정되지 못한 부분이 많다.

한국 연안 해역에서 출현이 보고된 90종의 와편모조류 시스트 종에는 특정 연구자에 특정 해역에서만 보고되는 종들이 다수 있어, 발아실험 등 제반 분류학적 검토가 필요한 부분은 있다고 하더라도, 현재 전 세계에서 보고되는 와편모조류 시스트가 150~200종을 고려하면(Matsuoka and Fukuyo 2000), 국내 출현종은 매우 다양하다고 할 수 있다(Table 3). 표에서 최근 새롭게 발견되는 현생 와편모조류 시스트는 별도의 고생물학적 이름을 붙이지 않고 유영세포의 종명을 시스트 이름을 이용하고 있음을 나타내고 있고, 과거 고생물학적 종명의 시스트를 발아시킬 경우, 현생 유영세포에서 상이한 종이 출현하고 있어, 하나의 유영세포 종명에 다수의 고생물학적 명칭이 나타나고 있는 점에 주의가 필요하다.

그리고 한국 연안 해역의 시스트 연구가 남해연안에 집중되어 있어, 출현종에 대한 생물·지리학적 검토가 큰 의미를 나타내는 것은 아니지만, 현재까지의 연구결과를 정리하는 입장에서 출현종별 출현해역과 문헌, 그리고 광학현미경 사진을 첨부하여 정리하여 둔다. 다만 일부 종

**Table 3.** Species list of dinoflagellate motile cell and cysts from modern sediments in Korean coastal area and adjoining sea

Plankton Science Name	Dinoflagellate cyst name (Paleontological Science Name)
<b>Autotrophic Species</b>	
<b>Calciodinoid Group</b>	
<i>Ensiculifera carinata</i> Matsuoka <i>et al.</i> 1990	Cyst of <i>Ensiculifera carinata</i> Matsuoka <i>et al.</i> 1990 (Plate I-1)
<i>Pentapharsodinium dalei</i> (Indelicato et Loeblich III 1 Montreso <i>et al.</i> 1993)	Cyst of <i>Pentapharsodinium dalei</i> (Indelicato et Loeblich III 1 Montreso <i>et al.</i> 1993)
<i>Scrippsiella crystallina</i> Lewis 1991	Cyst of <i>Scrippsiella crystallina</i> Lewis 1991
<i>Scrippsiella trochoidea</i> (Stein) Loeblich III 1976	Cyst of <i>Scrippsiella trochoidea</i> (Stein) Loeblich III 1976
<i>Scrippsiella</i> sp.	Cyst of <i>Scrippsiella</i> sp.
<b>Gonyaulacoid Group</b>	
<i>Alexandrium affinis</i> (Inoue et Fukuyo) Balech 1985	Cyst of <i>Alexandrium affinis</i> (Inoue et Fukuyo) Balech 1985
<i>Alexandrium catenatum</i> (Whedon et Kofoid) Balech 1985 / <i>tamarensis</i> (Lebour) Balech 1992 complex	Cyst of <i>Alexandrium catenatum</i> (Whedon et Kofoid) Balech 1985 / <i>tamarensis</i> (Lebour) Balech 1992 complex
<i>Alexandrium minutum</i> Halim 1960	Cyst of <i>Alexandrium minutum</i> Halim 1960
<i>Alexandrium</i> sp.	Cyst of <i>Alexandrium</i> sp.
<i>Gonyaulax digitalis</i> (Pouchet) Kofoid 1911	<i>Spiniferites bentori</i> (Rossignol) Wall et Dale 1970
<i>Gonyaulax elongata</i> (Reid) Ellegaard <i>et al.</i> 2003	<i>Spiniferites elongatus</i> Reid 1974
<i>Gonyaulax membranaceus</i> (Rossignol) Ellegaard <i>et al.</i> 2003	<i>Spiniferites membranaceus</i> (Rossignol) Sarjeant 1970
<i>Gonyaulax verior</i> Sourmia 1973	Cyst of <i>Gonyaulax verior</i> Sourmia 1973
<i>Gonyaulax scrippsae</i> Kofoid 1911	<i>Spiniferites bulloideus</i> (Deflandre et Cookson) Sarjeant 19705
<i>Gonyaulax spinifera</i> (Claparede et Lachmann) Diesing 1866 complex	<i>Ataxiodinium choane</i> Reid 1974
	<i>Nematosphaeropsis labyrinthus</i> (Ostenfeld) Reid 1974
	<i>Nematosphaeropsis</i> sp.
	<i>Spiniferites hypercanthus</i> (Deflandre et Cookson) Cookson et Eisenack 1974
	<i>Spiniferites mirabilis</i> (Rossignol) Sarjeant 1970
	<i>Spiniferites ramosus</i> (Ehrenberg) Mantell 1854
<i>Gonyaulax</i> sp.	<i>Bitectatodinium spongium</i> (Zonneveld) Zonneveld et Jurkschat 1999
	<i>Impagidinium aculeatum</i> (Well) Lentin et Williams 1981
	<i>Impagidinium</i> sp.
	<i>Spiniferites delicatus</i> Reid 1974
	<i>Spiniferites</i> spp.
<i>Lingulodinium polyedrum</i> (Stein) Dodge 1989	<i>Lingulodinium machaerophorum</i> (Deflandre et Cookson) Wall 1967
<i>Protoceratium reticulatum</i> (Claparde et Lachmann) Bütschli 1885	<i>Operculodinium centrocarpum</i> sensu Wall et Dale 1966
<i>Protoceratium</i> sp. cf. <i>reticulatum</i> (Claparde et Lachmann) Bütschli 1885	<i>Operculodinium israelianum</i> (Rossignol) Wall 1967
<i>Protoceratium</i> sp.	<i>Operculodinium crassum</i> Harland 1979
<i>Pyrodinium bahamense</i> var. <i>bahamense</i> Plate 1906	<i>Polysphaeridium zoharyi</i> (Rossignol) Bujak <i>et al.</i> 1980
<b>Gymnodinioid Group</b>	
<i>Cochlodinium polykrikoides</i> . Margalef 1961	Cyst of <i>Cochlodinium polykrikoides</i> . Margalef 1961
<i>Cochlodinium</i> sp.	Cyst of <i>Cochlodinium</i> sp.
<i>Gymnodinium catenatum</i> Graham 1943	Cyst of <i>Gymnodinium catenatum</i> Graham 1943
<i>Gymnodinium impudicum</i> (Fraga et Bravo) Hansen et Moestrup 2000	Cyst of <i>Gyrodinium impudicum</i> (Fraga et Bravo) Hansen et Moestrup 2000
<i>Gymnodinium</i> sp.	Cyst of <i>Gymnodinium</i> sp.
<i>Gyrodinium instriatum</i> Freudenthal et Lee 1963	Cyst of <i>Gyrodinium instriatum</i> Freudenthal et Lee 1963
<i>Gyrodinium</i> sp.	Cyst of <i>Gyrodinium</i> sp.
<i>Pheopolykrikos hartmannii</i> (Zimmermann) Matsuoka et Fukuyo 1986	Cyst of <i>Pheopolykrikos hartmannii</i> (Zimmermann) Matsuoka et Fukuyo 1986
<b>Tuberculodinioid Group</b>	
<i>Pyrophacus horologium</i> Stein 1883	Cyst of <i>Pyrophacus horologium</i> Stein 1883
<i>Pyrophacus steinii</i> (Schiller) Wall et Dale 1971	<i>Tuberculodinium vancampoae</i> (Rossignol) Wall 1967
<i>Pyrophacus</i> sp.	<i>Tuberculodinium</i> sp.
<b>Heterotrophic Species</b>	
<b>Diplosalioid Group</b>	
<i>Diplopelta parva</i> (Abe) Matsuoka 1988	Cyst of <i>Diplopelta parva</i> (Abe) Matsuoka 1988
<i>Diplosalis lenticula</i> Bergh 1881	Cyst of <i>Diplosalis lenticula</i> Bergh 1881
<i>Diplosalis</i> sp.	<i>Dulbridinium</i> sp.



Table 3. Continued

Plankton Science Name	Dinoflagellate cyst name (Paleontological Science Name)
<i>Gotoius abei</i> Matsuoka 1988	Cyst of <i>Gotoius abei</i> Matsuoka 1988
<i>Oblea acanthocysta</i> Kawami <i>et al.</i> 2006	Cyst of <i>Oblea acanthocysta</i> Kawami <i>et al.</i> 2006
<i>Preperidinium meunieri</i> (Pavillard) Elbrächter 1993	<i>Dulbridinium caperatum</i> Reid 1977
<b>Protopteridinioid Group</b>	
<i>Heterocapsa triquetra</i> (Ehrenberg) Stein 1883	Cyst of <i>Heterocapsa triquetra</i> (Ehrenberg), Stein 1883
<i>Peridinium limbatum</i> (Stokes) Lemmerman 1990	Cyst of <i>Peridinium limbatum</i> (Stokes) Lemmerman 1990
<i>Protopteridinium americanum</i> (Gran et Braarud) Balech 1974	Cyst of <i>Protopteridinium americanum</i> (Gran et Braarud) Balech 1974
<i>Protopteridinium avellanum</i> (Meunier) Balech 1974	<i>Brigantedinium cariacense</i> (Wall) Lentin et Williams 1993
<i>Protopteridinium claudicans</i> (Paulsen) Balech 1974	<i>Votadinium spinosum</i> Reid 1977
<i>Protopteridinium compressum</i> (Nie) Balech 1974	<i>Stelladinium abeii</i> Matsuoka 1985
	<i>Stelladinium reidii</i> Bradford 1975
	<i>Stelladinium stellatum</i> (Wall et Dale) Reid 1977
<i>Protopteridinium conicoides</i> (Paulsen) Balech 1973	<i>Brigantedinium simplex</i> Wall 1965 ex Lentin et Williams 1993
<i>Protopteridinium conicum</i> (Gran) Balech 1974	<i>Selenopemphix quanta</i> (Bradford) Matsuoka 1985
<i>Protopteridinium denticulatum</i> (Gran et Braarud) Balech 1974	<i>Brigantedinium irregulare</i> Matsuoka 1987
<i>Protopteridinium divaricatum</i> (Meunier) Balech 1988	<i>Xandarodinium xanthum</i> Reid 1977
<i>Protopteridinium latissimum</i> (Kofoid) Balech 1974	Cyst of <i>Protopteridinium latissimum</i> (Kofoid) Balech 1974
<i>Protopteridinium leonis</i> (Pavillard) Balech 1974	<i>Lejeunecysta sabrina</i> (Reid) Bujak 1984
	<i>Quinquecuspis concreta</i> Reid 1977
<i>Protopteridinium minutum</i> (Kofoid) Loeblich III 1970	Cyst of <i>Protopteridinium minutum</i> (Kofoid) Loeblich III 1970
<i>Protopteridinium oblongum</i> (Aurivillius) Parke et Dodge 1976	<i>Votadinium calvum</i> Reid 1977
<i>Protopteridinium petagonum</i> (Gran) Balech 1974	<i>Brigantedinium majusculum</i> Reid ex Lentin et Williams 1993
	<i>Trinovantedinium applanatum</i> (Bradford) Bujak et Davies 1983
	<i>Trinovantedinium capitatum</i> Reid 1977
<i>Protopteridinium stellatum</i> (Wall) Balech 1994	Cyst of <i>Protopteridinium stellatum</i> (Wall in Wall et Dale) Rocho <i>et al.</i> 1999
<i>Protopteridinium subinermis</i> (Paulsen) Loeblich III 1970	<i>Selenopemphix alticinctum</i> (Bradford) Matsuoka in Nehring 1997
	<i>Selenopemphix nephroides</i> (Benedek) Benedek et Sarjeant 1981
<i>Protopteridinium thorianum</i> (Paulsen) Balech 1974	Cyst of <i>Protopteridinium thorianum</i> (Paulsen) Balech 1974
<i>Protopteridinium</i> sp.	<i>Brigantedinium auranteum</i> Reid 1977
	<i>Brigantedinium asymmetricum</i> Matsuoka 1987
	<i>Brigantedinium grande</i> Matsuoka 1987
	<i>Brigantedinium</i> spp.
	<i>Echinidinium aculenatum</i> Zonneveld 1997
	<i>Echinidinium delicatum</i> Zonneveld 1997
	<i>Echinidinium</i> sp. cf. <i>delicatum</i> Zonneveld 1997
	<i>Echinidinium granulatum</i> Zonneveld 1997
	<i>Echinidinium</i> spp.
	<i>Islandinium brevispinosum</i> Pospelova et Head 2002
	<i>Islandinium minutum</i> (Harland et Reid in Harland <i>et al.</i> 1980) Head <i>et al.</i> 2001
	<i>Lejeunecysta aliva</i> (Reid 1977) Turon et Londeix 1988
	<i>Selenopemphix</i> sp.
	<i>Stelladinium bifurcatum</i> ?
	<i>Stelladinium robustum</i> Zonneveld 1997
	<i>Trinovantedinium pallidifolium</i> Matsuoka 1987
<b>Gymnodinioid Group</b>	
<i>Polykrikos kofoidii</i> Chatton 1914	Cyst of <i>Polykrikos kofoidii</i> Chatton 1914
<i>Polykrikos schwartzii</i> Bütschli 1873	Cyst of <i>Polykrikos schwartzii</i> Bütschli 1873
<i>Polykrikos</i> sp.	Cyst of <i>Polykrikos</i> sp.

90 species as cyst name, 61 species as motile phytoplankton

에 대해서는 현미경 사진을 제시하지 못하였고, 출현종은 시스트를 이용한 부영양화 과정 평가 수단으로 독립영양종과 종속영양종으로 구분하였지만 (Dale *et al.* 1999; Matsuoka 1999, 2001, 2011; Dale 2000, 2001, 2009), 외편

모조류 유영세포에서 완전 독립영양을 하는 종은 수중에 지나지 않고 많은 종에서 반독립영양이나 종속영양을 수행하고 있어 (Taylor 1987), 단순히 독립영양종과 종속영양종으로 구분하는 것에 대해서도 논쟁이 되고 있다.

**AUTOTROPHIC SPECIES****Order GONYAULACALES Taylor 1980****Family CALCOIDINELLACEAE Taylor 1987  
(Calcioidineloid Group)****Genus *Ensiculifera* Balech 1967**

*Ensiculifera carinata* Matsuoka *et al.* 1990

Paleontological name: cyst of *Ensiculifera carinata* Matsuoka *et al.* 1990 (Plate I-1)

Distribution: Gamak bay (Shin *et al.* 2012), western South Sea (Shin *et al.* 2007)

**Genus *Pentapharsodinium* Indelicato et Loeblich III 1986**

*Pentapharsodinium dalei* (Indelicato et Loeblich III 1986) Montreso *et al.* 1993

Paleontological name: *Pentapharsodinium dalei* (Indelicato et Loeblich III) Montreso *et al.* 1993 (Plate I-2)

Synonym: *Peridinium faeroense* Dale 1977

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

**Genus *Scrippsiella* Balech ex Loeblich III 1965**

*Scrippsiella crystallina* Lewis 1991

Paleontological name: cyst of *Scrippsiella crystallina* Lewis 1991 (Plate I-3)

Distribution: Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), East China Sea (Cho *et al.* 2003)

*Scrippsiella trochoidea* (Stein) Loeblich III 1976

Paleontological name: cyst of *Scrippsiella trochoidea* (Stein) Loeblich III 1976 (Plate I-4)

Distribution: Yeongil bay (Kim and Han 2000), Jinhae-Masan bay (Lee *et al.* 1998; Park and Shim 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park *et al.* 2004; Shin *et al.* 2010, 2012; Park and Shim 2011; Shin *et al.* 2013), central South Sea (Lee and Matsuoka 1996; Cho *et al.* 2003; Park *et al.* 2005), western South Sea (Shin *et al.* 2007; Park *et al.* 2008) Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001)

*Scrippsiella* sp./spp.

Paleontological name: cyst of *Scrippsiella* sp. (Plate I-5)

Distribution: Tongyeong coasts (Kang *et al.* 1999), Bokdol-bada (Shin *et al.* 2011), central South Sea (Lee and Matsuoka 1996), Yellow Sea (Cho and Matsuoka 2001; Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001)

**Family GONIODOMATACEAE Lindemann 1928  
(Gonyaulacoid Group)****Genus *Alexandrium* Halim 1928**

*Alexandrium affinis* (Inoue et Fukuyo 1985) Balech 1985

Paleontological name: cyst of *Alexandrium affinis* (Inoue et Fukuyo 1985) Balech 1985 (Plate I-6)

Synonym: *Protogonyaulax affinis* Inoue et Fukuyo 1985  
*A. fukuyoi* Balech 1985

Distribution: Jinhae-Masan bay (Kim 1991; Park and Shim 2011), Gamak bay (Lee *et al.* 1999; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yejoa bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), eastern South Sea (Kim *et al.* 1990), Bokdol-bada (Shin *et al.* 2011), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho *et al.* 2001; Kim *et al.* 2010)

*Alexandrium catenatum* (Whedon et Kofoid) Balech 1985/  
*A. tamarense* (Lebour) Balech 1992

Paleontological name: cyst of *Alexandrium catenatum/tamarense* complex (Plate I-7)

Synonym: *Gonyaulax catenatum* Whedon et Kofoid 1936

*Gessnerium catenatum* (Whedon et Kofoid) Loeblich III et L. Loeblich 1979

*Protogonyaulax catenatum* (Whedon et Kofoid) Taylor 1979

*Gonyaulax tamarensis* Lebour 1925

*G. tamarensis* var. *excavata* Braarud 1945

*G. excavata* (Braarud) Balech 1971

*Gessnerium tamarensis* (Lebour) Loeblich III et L. Loeblich 1979

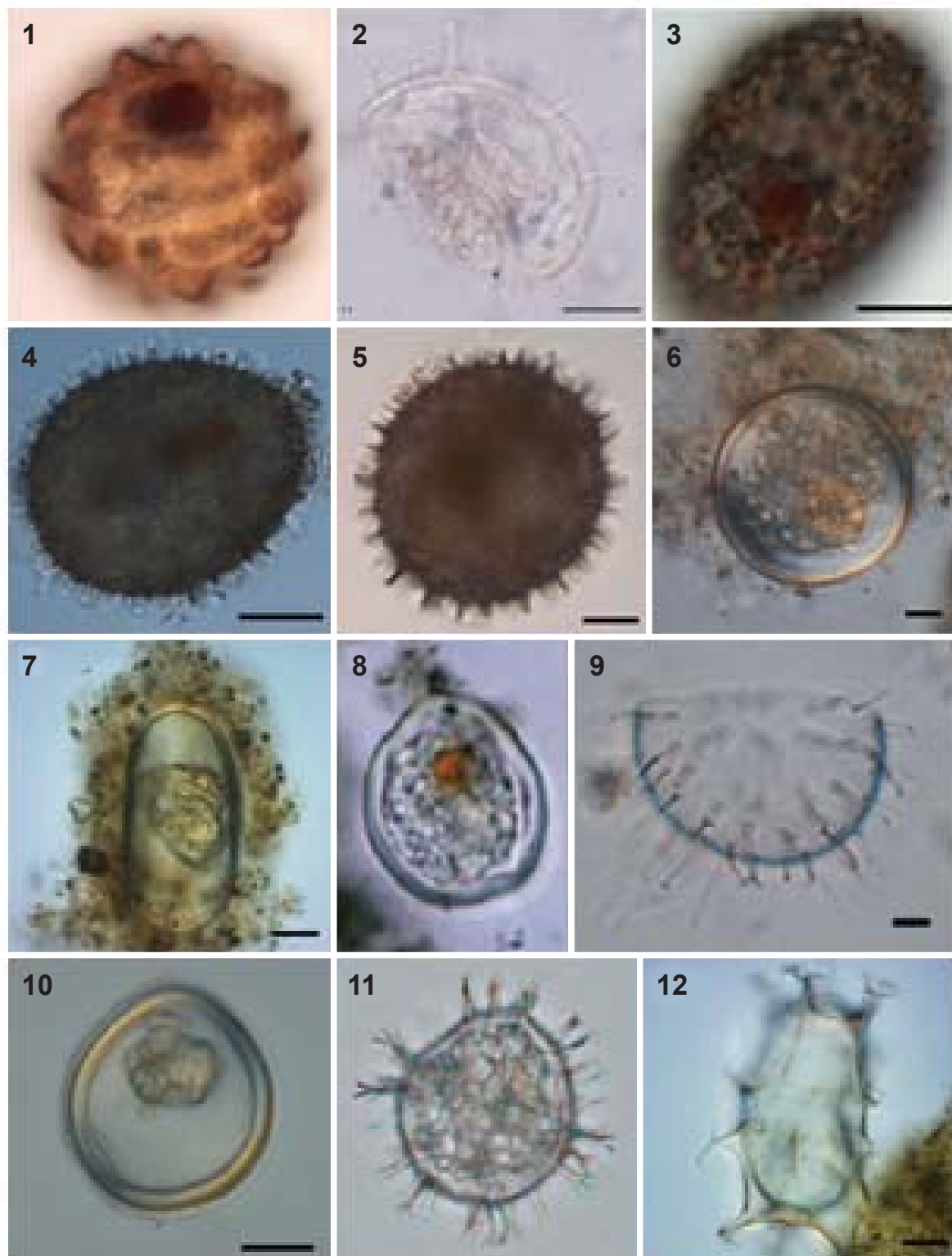
*Protogonyaulax tamarensis* (Lebour) Taylor 1979

*A. excavata* (Braarud) Balech et Tangen 1985

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon *et al.* 1993; Lee *et al.* 1998; Park and Shim 2011), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yejoa bay (Shin *et al.* 2010a; Shin *et al.* 2011),



## Autotrophic species



**Plate I.** Light microscope photographs of dinoflagellate cysts from Korean coastal waters. 1. cyst of *Enciculifera carinata*, 2. cyst of *Pentaparsodinium dalei*, 3. cyst of *Scrippsiella crystallina*, 4. cyst of *Scrippsiella trochoidea*, 5. cyst of *Scrippsiella* sp., 6. cyst of *Alexandrium affinis*, 7. cyst of *Alexandrium catenatum/tamarense*, 8. cyst of *Alexandrium minutum*, 9. *Polysphaeridium zoharyi*, 10. cyst of *Alexandrium* sp., 11. *Spiniferites bentori*, 12. *Spiniferites elongatus* (scale bar=10  $\mu$ m).

Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999; Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2004)

*Alexandrium minutum* Halim 1960

Paleontological name: cyst of *Alexandrium minutum* Halim 1960 (Plate I-8)

Synonym: *A. ibericum* Balech 1985

Distribution: Gamak bay (Park and Shim 2011), Seamangeum coasts (Park and Shim 2011), East China Sea (Kim *et al.* 2010)

*Alexandrium* sp.

Paleontological name: cyst of *Alexandrium* sp. (Plate I-10).

Distribution: Jinhae-Masan bay (Lee *et al.* 1998), Gwangyang bay (Kim *et al.* 2003a, b), central South Sea (Lee and Matsuoka 1996; Cho *et al.* 2003), Seamangeum coasts (Park *et al.* 2004), Yellow Sea (Cho and Matsuoka 2001; Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003)

Remarks: 문헌에 따라서는 *Alexandrium*속의 시스트를 종까지 분류하지 않고 *Alexandrium* sp./spp.로 포괄적 표현을 하거나, 타원형, 구형 등으로 전체적인 형태만을 표현하고 있음.

### Genus *Pyrodinium* Plate 1906

*Pyrodinium bahamense* var. *compressum* (Böhm) Steidinger *et al.* 1980

Paleontological name: *Polysphaeridium zoharyi* (Rossignol) Bujak *et al.* 1980

Distribution: Tongyeong coasts (Pospelova and Kim 2010), Yellow Sea (Hwang *et al.* 2009)

### Family GONYAULACEAE Lindemann 1928

#### (Gonyaulacoid Group)

### Genus *Gonyaulax* Diesing 1866

*Gonyaulax digitalis* (Pouchet) Kofoid 1991

Paleontological name: *Spiniferites bentori* (Rossigno) Wall et Dale 1970 (Plate I-11)

Synonym: *G. digitale* Lemmerman 1899

*Protoperidinium digitale* Pouchet 1883

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Moon *et al.* 1993; Lee *et al.* 1998; Park and Shim 2011), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Park and Shim 2011; Shin *et al.* 2011), Tongyeong coasts (Pospelova and Kim 2010), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003)

*Gonyaulax elongata* (Reid) Ellegaard *et al.* 2003

Paleontological name: *Spiniferites elongatus* Reid 1974 (Plate I-12)

Distribution: Jinhae-Masan bay (Kim 1991; Moon *et al.* 1993; Lee and Matsuoka 1996; Lee *et al.* 1998; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011), Yeolja bay (Shin *et al.* 2010a), Tongyeong coasts (Kang *et al.* 1999; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001)

Remarks: 많은 문헌에서 유영세포의 명칭을 *Gonyaulax spinifera* complex로 표현하고 있음.

*Gonyaulax membranaceus* (Rossignol) Ellegaard *et al.* 2003

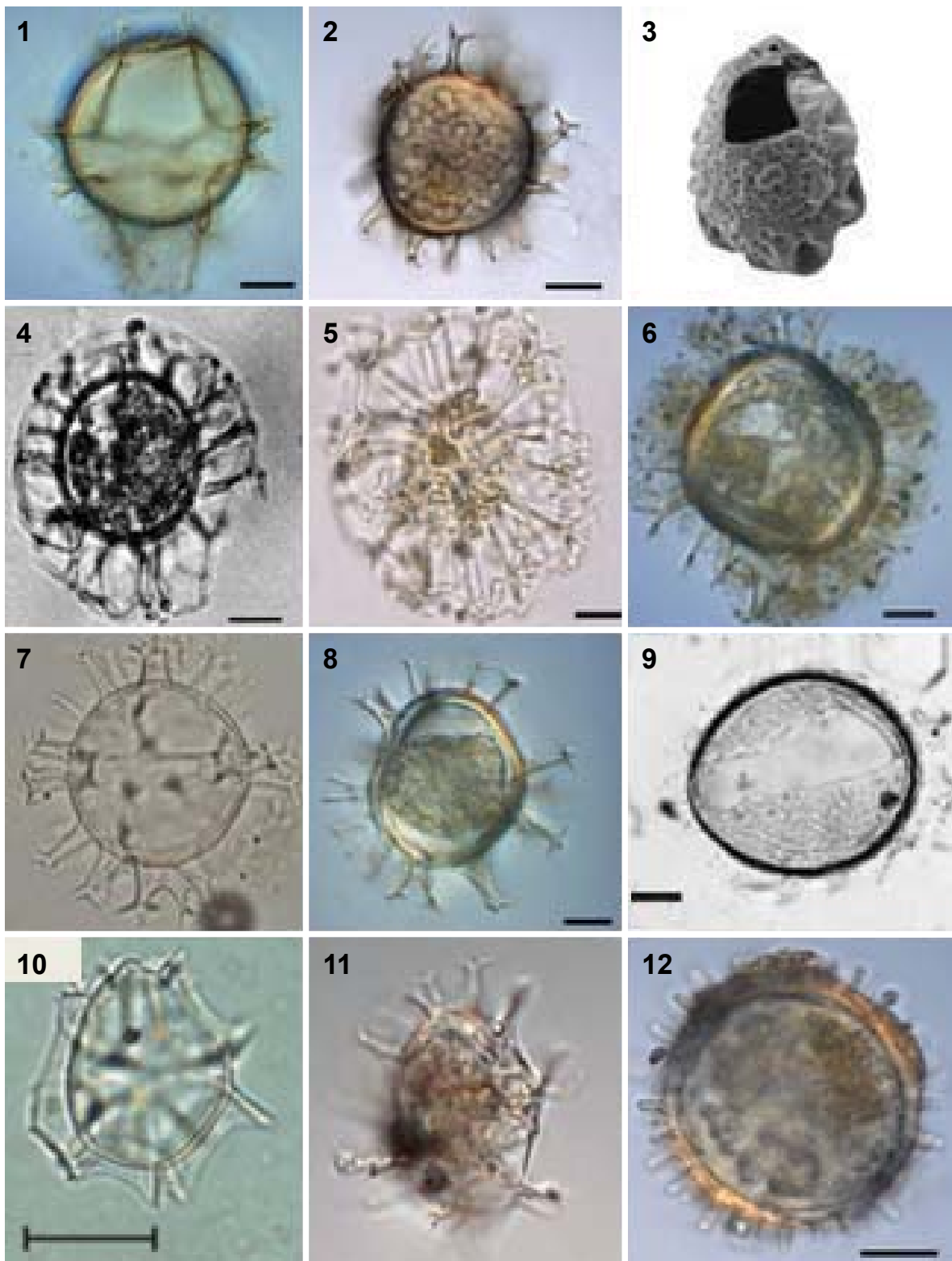
Paleontological name: *Spiniferites membranaceus* (Rossignol) Sarjeant 1970 (Plate II-1)

Distribution: Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Park and Yoon 2003; Park *et al.* 2004), Tongyeong coasts ((Pospelova and Kim 2010), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001)

Remarks: 많은 문헌에서 유영세포의 명칭을 *Gonyaulax spinifera* complex로 표현되고 있음.

*Gonyaulax verior* Sournia 1973

Paleontological name: cyst of *Gonyaulax verior* Sournia 1973



**Plate II.** Light microscope photographs of dinoflagellate cysts from Korean coastal waters. 1. *Spiniferites membranaceus*, 2. *Spiniferites bulloideus*, 3. *Ataxiodinium choane*, 4. *Nematosphaeropsis labyrinthus*, 5. *Nematosphaeropsis* sp., 6. *Spiniferites hypercanthus*, 7. *Spiniferites mirabilis*, 8. *Spiniferites ramosus*, 9. *Bitectatodinium spongium*, 10. *Impagidinium aculeatum*, 11. *Spiniferites delicatus*, 12. *Lingulodinium machaerophorum*.

Synonym: *Amylax diacantha* Meunier 1919

*Gonyaulax diacantha sensu* Schiller 1937

Distribution: Gamak bay (Lee *et al.* 1999; Park and Shim 2011), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Hwang *et al.* 2009)

*Gonyaulax scrippsae* Kofoid 1911

Paleontological name: *Spiniferites bulloideus* (Deflandre et Cookson) Sarjeant 1905 (Plate II -2)

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee and Matsuoka 1996; Lee *et al.* 1998; Park and Shim 2011; Shin *et al.* 2011), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999; Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004), Yellow Sea (Cho and Matsuoka 2001; Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004; Kim *et al.* 2010)

*Gonyaulax spinifera* (Claparede et Lachmann) Diesing 1866 complex

Paleontological name: *Ataxiodinium choane* Reid 1974 (Plate II-3)

Synonym: *Peridinium spinifera* Claparede et Lachmann 1859

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Gonyaulax spinifera* complex

Paleontological name: *Nematosphaeropsis labyrinthus* (Ostenfeld 1903) Reid 1974 (Plate II-4)

Distribution: East China Sea (Kim *et al.* 2010)

*Gonyaulax spinifera* complex

Paleontological name: *Nematosphaeropsis* sp. (Plate II-5)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Gonyaulax spinifera* complex

Paleontological name: *Spiniferites hypercanthus* (Deflandre et Cookson) Cookson et Eisenack 1974 (Plate II-6)

Distribution: Busan harbor (Kim *et al.* 2005), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004; Kim *et al.* 2010)

*Gonyaulax spinifera* complex

Paleontological name: *Spiniferites mirabilis* (Rossignol) Sarjeant 1970 (Plate II-7)

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Moon *et al.* 1993), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2012), Geoje coast (Shin *et al.* 2007), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim, 2011), Yellow Sea (Cho and Matsuoka, 2001), East China Sea (Cho and Matsuoka, 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004; Kim *et al.* 2010)

*Gonyaulax spinifera* complex

Paleontological name: *Spiniferites ramosus* (Ehrenberg) Mantell 1854 (Plate II-8)

Distribution: Busan harbor (Kim *et al.* 2005), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Park and Yoon 2003; Park *et al.* 2004; Park and Shim 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Pospelova and Kim 2010; Park and Shim 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004; Kim *et al.* 2010)

*Gonyaulax* sp.

Paleontological name: *Bitectatodinium spongium* (Zonneveld) Zonneveld et Jurkschat 1999 (Plate II-9)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Gonyaulax* sp.

Paleontological name: *Impagidinium aculeatum* (Well) Len-

tin et Williams 1981 (Plate II-10)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Gonyaulax* sp.

Paleontological name: *Impagidinium* sp.

Distribution: Tongyeong coasts (Pospelova and Kim 2010), East China Sea (Cho et al. 2003; Kim et al. 2010)

*Gonyaulax* sp.

Paleontological name: *Spiniferites delicatus* Reid 1974 (Plate II-11)

Distribution: Gwangyang bay (Kim et al. 2003a, b), Jinhae-Masan bay (Moon et al. 1993), Gamak bay (Park et al. 2004; Shin et al. 2010b), Yeolja bay (Shin et al. 2010a), Tongyeong coasts (Kang et al. 1999), central South Sea (Cho et al. 2003; Park et al. 2005), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho et al. 2004; Kim et al. 2010)

*Gonyaulax* sp.

Paleontological name: *Spiniferites* spp.

Distribution: Busan harbor (Kim et al. 2005), Jinhae-Masan Bay (Moon et al. 1993), Gwangyang bay (Kim et al. 2003a, b), Gamak bay (Park and Yoon 2003; Park et al. 2004; Shin et al. 2010b; Shin et al. 2011; Shin et al. 2012), Yeolja bay (Shin et al. 2010a; Shin et al. 2011), Geoje coast (Shin et al. 2007), Tongyeong coasts (Kang et al. 1999; Pospelova and Kim 2010), Bokdol-bada (Shin et al. 2011), western South Sea (Shin et al. 2007), central South Sea (Lee and Matsuoka 1996; Cho et al. 2003; Park et al. 2005), Seamangeum coasts (Park et al. 2004; Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001; Hwang et al. 2009), East China Sea (Cho and Matsuoka 2001; Cho et al. 2003; Cho et al. 2004; Kim et al. 2010)

#### Genus *Lingulodinium* (Stein) Dodge 1989

*Lingulodinium polyedrum* (Stein) Dodge 1989

Paleontological name: *Lingulodinium machaerophorum* (Deflandre et Cookson) Wall 1967 (Plate II-12)

Synonym: *Gonyaulax polyedra* Stein 1833

Distribution: Jinhae-Masan bay (Kim 1991; Moon et al. 1993; Park and Shim 2011), Gwangyang bay (Kim et al. 2003a, b), Gamak bay (Lee et al. 1999; Park and Yoon 2003; Park et al. 2004; Shin et al. 2010b; Park and Shim 2011; Shin

et al. 2011; Shin et al. 2012), Yeolja bay (Shin et al. 2010a; Shin et al. 2011), Geoje coast (Shin et al. 2007), Tongyeong coasts (Pospelova and Kim 2010), Bokdol-bada (Shin et al. 2011), western South Sea (Shin et al. 2007), central South Sea (Cho et al. 2003; Park et al. 2005), Seamangeum coasts (Park et al. 2004; Park and Shim 2011), Yellow Sea (Hwang et al. 2009), East China Sea (Cho et al. 2001; Cho et al. 2003; Cho et al. 2004; Kim et al. 2010)

#### Genus *Protoceratium* Bergh 1881

*Protoceratium reticulatum* (Claparde et Lachmann) Bütschli 1885

Paleontological name: *Operculodinium centrocarpum* sensu Wall et Dale 1966 (Plate III-1)

Synonym: *Gonyaulax grindleyi* Reinecke 1967

Distribution: Jinhae-Masan bay (Kim 1991; Moon et al. 1993; Lee et al. 1998; Park and Shim 2011), Gwangyang bay (Kim et al. 2003a), Gamak bay (Lee et al. 1999; Park and Yoon 2003; Park et al. 2004; Shin et al. 2010b; Park and Shim 2011; Shin et al. 2011; Shin et al. 2012), Yeolja bay (Shin et al. 2010a; Shin et al. 2011), Geoje coast (Shin et al. 2007), Tongyeong coasts (Pospelova and Kim 2010), Bokdol-bada (Shin et al. 2011), western South Sea (Shin et al. 2007), central South Sea (Cho et al. 2003; Park et al. 2005), Seamangeum coasts (Park et al. 2004; Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001; Hwang et al. 2009), East China Sea (Cho and Matsuoka 2001; Cho et al. 2001; Cho et al. 2003; Cho et al. 2004; Kim et al. 2010)

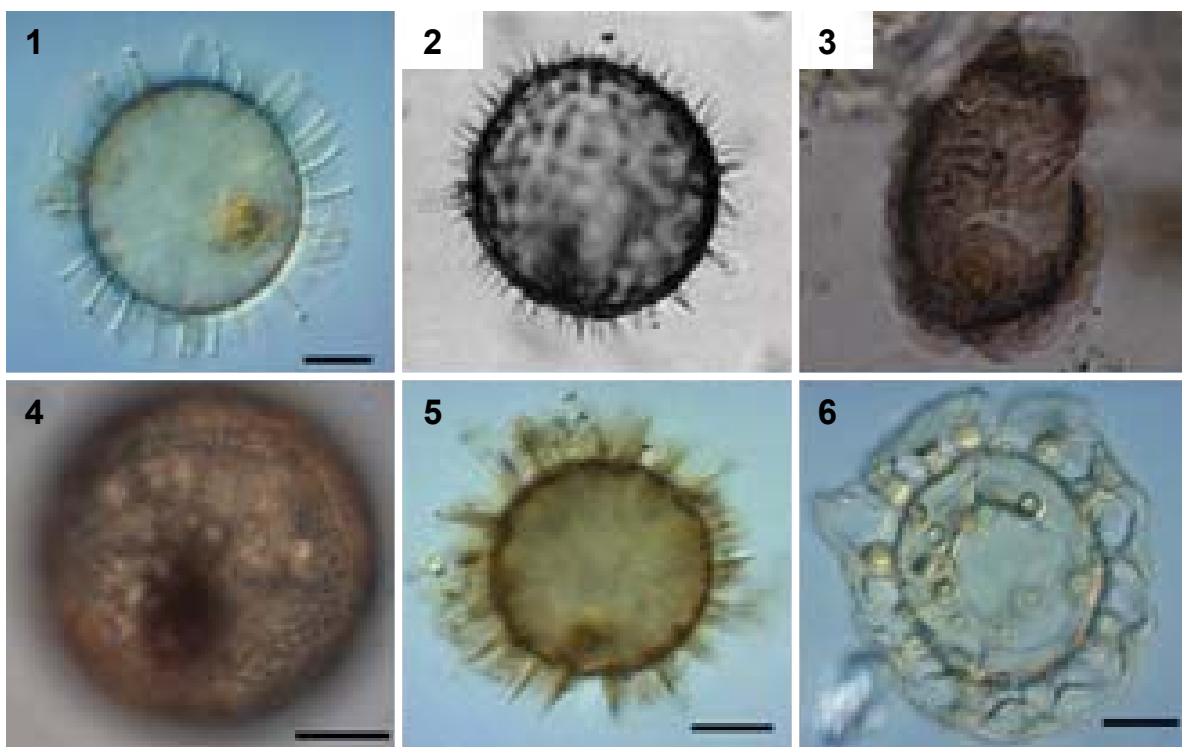
*Protoceratium* sp. cf. *reticulatum* (Claparde et Lachmann) Bütschli 1885

Paleontological name: *Operculodinium israelianum* (Rossignol) Wall 1967 (Plate III-2)

Distribution: Jinhae-Masan bay (Moon et al. 1993), Gamak bay (Park and Yoon 2003; Park et al. 2004), Geoje coast (Shin et al. 2007), Tongyeong coasts (Pospelova and Kim 2010), western South Sea (Shin et al. 2007), central South Sea (Cho et al. 2003; Park et al. 2005), East China Sea (Cho and Matsuoka 2001; Cho et al. 2001; Cho et al. 2003; Kim et al. 2010)

Remarks: 유영세포에서는 중 수준까지 동정이 되지 못함.

*Protoceratium* sp.



**Plate III.** Light microscope photographs of dinoflagellate cysts from Korean coastal waters. 1. *Operculodinium centrocarpum* sensu, 2. *Operculodinium israelianum*, 3. cyst of *Cochloclodinium* sp., 4. cyst of *Gymnodinium catenatum*, 5. cyst of *Pheopolykrikos hartmannii*, 6. *Tuberculodinium vancampoae*.

Paleontological name: *Operculodinium crassum* Harland 1979

Distribution: East China Sea (Cho *et al.* 2003)

Remarks: 유영세포에서는 종 수준까지 동정이 되지 못함.

#### Order GYMNODINIALES Lemmermann 1910

##### Family GYMNODINIACEAE Lankester 1885

##### (Gymnodinioid Group)

##### Genus *Cochloclodinium* Schütt 1896

*Cochloclodinium polykrikoides*. Margalef 1961

Paleontological name: cyst of *Cochloclodinium polykrikoides* Margalef 1961

Synonym: *C. heterlobatum* Silva 1967

Distribution: Jinhae-Masan bay (Park and Shim 2011), Tongyeong coasts (Pospelova and Kim 2010)

Remarks: 휴면포자인 cyst 존재에 대해 오랜 기간 토론 대상이 되었던 종으로 아직도 명확하지 못함 점은 남아있지만, 최근 새로운 연구결과 (Matsuoka *et al.* 2010; Tang *et al.* 2012)를 참고로 하여 본 종의 시스트명을 사용함.

*Cochloclodinium* sp.

Paleontological name: cyst of *Cochloclodinium* sp. (Plate III-3)

Distribution: Jinhae-Masan bay (Lee *et al.* 1998), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Park and Shim 2011; Shin *et al.* 2012), Tongyeong coasts (Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Park *et al.* 2005), eastern South Sea (Kim *et al.* 1990), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho and Matsuoka 2001)

Remarks: cyst of *Cochloclodinium polykrikoides* 존재가 분명하여 짐에 따라 *C. polykrikoides* 시스트로 소속을 변경하여야 할 내용도 있지만, cyst of *Cochloclodinium* sp.가 별도 종으로 존재하고 있어, 원 논문의 표현을 그대로 사용하고 있음.

##### Genus *Gymnodinium* Stein 1878

*Gymnodinium catenatum* Graham 1943

Paleontological name: cyst of *Gymnodinium catenatum* Graham 1943 (Plate III-4)



Distribution: Gwangyang bay (Kim *et al.* 2003a), Gamak bay (Park and Yoon 2003; Park *et al.* 2004; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Hwang *et al.* 2009),

*Gymmodinium impudicum* (Fraga et Bravo) Hansen et Moestrup 2000

Paleontological name: cyst of *Gyrodinium impudicum* (Fraga et Bravo) Hansen et Moestrup

Synonym: *Gyrodinium impudicum* Fraga et Bravo 1995

Distribution: Tongyeong coasts (Park and Shim 2011), Seamangeum coasts (Park and Shim 2011)

*Gymnodinium* sp.

Paleontological name: cyst of *Gymnodinium* sp.

Distribution: Jinhae-Masan bay (Lee and Matsuoka 1996; Lee *et al.* 1998), Tongyeong coasts (Kang *et al.* 1999), Gamak bay (Lee *et al.* 1999)

#### **Genus *Gyrodinium* Kofoid et Swezy 1921**

*Gyrodinium instriatum* Freudenthal et Lee 1963

Paleontological name: cyst of *Gyrodinium instriatum* Freudenthal et Lee 1963

Distribution: Jinhae-Masan bay (Kim 1991; Moon *et al.* 1993), Gamak bay (Park and Yoon 2003; Park *et al.* 2004), Eastern South Sea (Kim *et al.* 1990), Seamangeum coasts (Park and Shim 2011)

*Gyrodinium* sp.

Paleontological name: cyst of *Gyrodinium* sp.

Distribution: Jinhae-Masan bay (Lee and Yoo 1991; Lee *et al.* 1998), Tongyeong coasts (Kang *et al.* 1999), Gamak bay (Lee *et al.* 1999)

#### **Genus *Pheopolykrikos* Chatton 1933**

*Pheopolykrikos hartmannii* (Zimmermann) Matsuoka et Fukuyo 1986

Paleontological name: cyst of *Pheopolykrikos hartmannii*

(Zimmermann) Matsuoka et Fukuyo 1986 (Plate III-5)

Synonym: *Polykrikos hartmannii* Zimmermann 1930

Distribution: Jinhae-Masan bay (Kim 1991; Moon *et al.* 1993; Lee *et al.* 1998; Park and Shim 2011), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999; Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), eastern South Sea (Kim *et al.* 1990), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011)

#### **Family PYROCYSTACEAE (Schütt) Lemmerman 1899 (Tuberculodinioid Group)**

##### **Genus *Pyrophacus* Murray ex Lemmerman 1899**

*Pyrophacus horologium* Stein 1883

Paleontological name: cyst of *Pyrophacus horologium* (?)

Distribution: Jinhae-Masan bay (Kim 1991)

Remarks: 시스트 형성 여부가 확실하지 않음.

*Pyrophacus steinii* (Schiller) Wall et Dale 1971

Paleontological name: *Tuberculodinium vancampoae* (Rosignol) Wall 1967 (Plate III-6)

Synonym: *Pyrophacus horologium* var. *steinii* Schille 1935

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon *et al.* 1993; Lee *et al.* 1998), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Pospelova and Kim 2010), western South Sea (Shin *et al.* 2007), central South Sea (Lee and Matsuoka 1996; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001; Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004; Kim *et al.* 2010)

*Pyrophacus* sp.

Paleontological name: *Tuberculodinium* sp.

Distribution: East China Sea (Cho and Matsuoka 2001)

**Heterotrophic Species****Order PERIDINIALES Haeckel 1984****Family KOLKWTZIELLACEAE Lindemann 1928  
(Diplosalioid Group)****Genus *Diplopelta* Stein ex Jørgensen 1912**

*Diplopelta parva* (Abe) Matsuoka 1988

Paleontological name: cyst of *Diplopelta parva* (Abe) Matsuoka 1988

Synonym: *Dissodinium parvum* Abe 1941

Distribution: Gamak bay (Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011), Geoje coast (Shin *et al.* 2007), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003)

**Genus *Diplosalis* Bergh 1881**

*Diplosalis lenticula* Bergh 1881

Paleontological name: cyst of *Diplosalis lenticula* Bergh 1881

Synonym: *Peridiniopsis lentacula* (Bergh) Starmach 1974

*Diplosalis lenticulata* Stein 1883

*Glenodinium lentacula* (Bergh) Schiller

*Dissodinium lentacula* (Bergh) Loeblich III 1973

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee *et al.* 1998; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Park and Shim 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999; Park and Shim 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003), Seamangeum coasts (Park and Shim 2011), Yellow Sea (Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004)

*Diplosalis* sp.

Paleontological name: *Dulbridinium* sp.

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

**Genus *Gotoius* Abe ex Matsuoka 1988**

*Gotoius abei* Matsuoka 1988

Paleontological name: cyst of *Gotoius abei* Matsuoka 1988

Distribution: Seamangeum coasts (Park and Shim 2011)

**Genus *Oblea* Balech ex Loeblich Jr. et Loeblich III 1966**

*Oblea acanthocysta* Kawami *et al.* 2006

Paleontological name: cyst of *Oblea acanthocysta* Kawami *et al.* 2006 (Plate IV-1)

Distribution: Gamak bay (Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a)

**Genus *Preperidium* Mangin 1913**

*Preperidium meunieri* (Pavillard), Elbrächter 1993

Paleontological name: *Dulbridinium caperatum* Reid 1977 (Plate IV-2)

Synonym: *Peridinium paulsenii* Mangin 1911

*Diplopsalis minor* (Paulsen) Lindermann 1927

*Zygabikodinium lenticulatum* Loeblich III Jr et Loeblich III 1970

*Peridinium lenticulatum* Mangin 1911

*P. paulsenii* Mangin 1911

*Diplopsalis lenticula* f. *minor* Paulsen

Distribution: Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon *et al.* 1993; Lee *et al.* 1998; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Geoje coast (Shin *et al.* 2007), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Tongyeong coasts (Kang *et al.* 1999; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), central South Sea (Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), East China Sea (Cho and Matsuoka 2001)

**Family PERIDINIACEAE Ehrenberg 1831  
(Diplosalioid Group)****Genus *Heterocapsa* Stein 1883**

*Heterocapsa triquetra* (Ehrenberg) Stein 1883

Paleontological name: cyst of *Heterocapsa triquetra* (Ehrenberg) Stein 1883

Distribution: Jinhae-Masan bay (Kim 1991), eastern South Sea (Kim *et al.* 1990),

Remarks: 시스트 형성 여부가 확실하지 않음.

**Genus *Peridinium* Ehrenberg 1832**

*Peridinium limbatum* (Stokes) Lemmerman 1990

Paleontological name: cyst of *Peridinium limbatum* (Stokes)

## Heterotrophic Species



**Plate IV.** Light microscope photographs of dinoflagellate cysts from Korean coastal waters. 1. cyst of *Oblea acanthocysta*, 2. *Dulbridinium caperatum*, 3. cyst of *Protoperidinium americanum*, 4. *Brigantedinium cariacense*, 5. *Votadinium spinosum*, 6. *Stelladinium stellatum*, 7. *Brigantedinium simplex*, 8. *Selenopembix quanta*, 9. *Brigantedinium irregulare*, 10. *Xandarodinium xanthum*, 11. cyst of *Protoperidinium latissimum*, 12. *Lejeunecysta sabrina*.

Lemmerman 1990

Synonym: *Protoperidinium limbatum* Stockes 1888

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

### Genus *Protoperidinium* Taylor 1987

*Protoperidinium americanum* (Gran et Braarud) Balech 1974

Paleontological name: cyst of *Protoperidinium americanum* (Gran et Braarud) Balech 1974 (Plate IV-3)

Synonym: *Peridinium americanum* Gran et Braarud 1935

Distribution: Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999), Bokdol-bada (Shin *et al.* 2011), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), western South Sea (Shin *et al.* 2007), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2004)

*Protoperidinium avellana* (Meunier) Balech 1974

Paleontological name: *Brigantedinium cariacense* (Wall) Lentin et Williams 1993 (Plate IV-4)

Synonym: *Peridinium avellana* (Meunier) Lebour 1925

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2011), Tongyeong coasts (Pospelova and Kim 2010), Bokdol-bada (Shin *et al.* 2011), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2004)

*Protoperidinium claudicans* (Paulsen) Balech 1974

Paleontological name: *Votadinium spinosum* Reid 1977 (Plate IV-5)

Synonym: *Peridinium claudicans* Paulsen 1907

Distribution: Jinhae-Masan bay (Moon *et al.* 1993), Gwangyang bay (Kim *et al.* 2003a), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Tongyeong

coasts (Kang *et al.* 1999; Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), East China Sea (Cho and Matsuoka 2001)

*Protoperidinium compressum* (Abe) Balech 1974

Paleontological name: *Stelladinium abeii* Matsuoka 1985

*Stelladinium reidii* Bradford 1975

*Stelladinium stellatum* (Wall et dale 1968) Reid 1977 (Plate IV-6)

Synonym: *Peridinium compressum* (Abe) Nie

*Pongruentinium compressum* Abe 1927

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Moon *et al.* 1993; Lee and Matsuoka 1996; Lee *et al.* 1998; Park and Shim 2011), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Pospelova and Kim 2010), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004)

*Protoperidinium conicoides* (Paulsen) Balech 1973

Paleontological name: *Brigantedinium simplex* Wall 1965 ex Lentin et Williams 1993 (Plate IV-7)

Synonym: *Peridinium conicoides* Paulsen 1907

Distribution: Busan harbor (Kim *et al.* 2005), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a), Tongyeong coasts (Pospelova and Kim 2010), Geoje coast (Shin *et al.* 2007), Bokdol-bada (Shin *et al.* 2011), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2004)

*Protoperidinium conicum* (Gran) Balech 1974

Paleontological name: *Selenopembix quanta* (Bradford 1975) Matsuoka 1985 (Plate IV-8)

Synonym: *Peridinium conicum* (Gran) Ostfeld et Schmidt 1905

*Peridinium divergens* var. *conica* Gran 1900

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon *et al.* 1993; Lee *et al.* 1998; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Tongyeong coasts (Kang *et al.* 1999; Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Lee and Matsuoka 1996; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004), Yellow Sea (Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004; Kim *et al.* 2010)

*Protoperidinium denticulatum* (Gran et Braarud) Balech 1974

Paleontological name: *Brigantedinium irregulare* Matsuoka 1987 (Plate IV-9)

Synonym: *Protoperidinium clavus* Abe 1936

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Moon *et al.* 1993; Park and Shim 2011), Gamak bay (Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Bokdol-bada (Shin *et al.* 2011), central South Sea (Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho *et al.* 2004)

*Protoperidinium divaricatum* (Meunier) Parke et Dodge 1976

Paleontological name: *Xandarodinium xanthum* Reid 1977 (Plate IV-10)

Synonym: *P. gainii* (Dangeard) Balech 1974

*Protoperidinium divaricatum* (Meunier) Balech 1988

Distribution: Gamak bay (Park and Yoon 2003; Park *et al.* 2004), Tongyeong coasts (Pospelova and Kim 2010), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), Seamangeum coasts (Park and Shim 2011), East China Sea (Kim *et al.* 2010)

*Protoperidinium latissimum* (Kofoid) Balech 1974

Paleontological name: cyst of *Protoperidinium latissimum* (Kofoid) Balech 1974 (Plate IV-11)

Synonym: *Protoperidinium exiquipes* (Mangin) Dodge

*Protoperidinium pentagonoides* Balech 1949

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Lee and Yoo 1991; Lee *et al.* 1998), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2004)

*Protoperidinium leonis* (Pavillard) Balech 1974

Paleontological name 1: *Lejeunecysta sabrina* (Reid 1977) Bujak 1984 (Plate IV-12)

Synonym: *Peridinium leonis* Pavillard 1916

Distribution: Jinhae-Masan bay (Lee *et al.* 1998), Tongyeong coasts (Pospelova and Kim 2010), central South Sea (Cho *et al.* 2003), East China Sea (Cho and Matsuoka 2001)

Paleontological name 2: *Quinquecuspis concreta* Reid 1977 (Plate V-1)

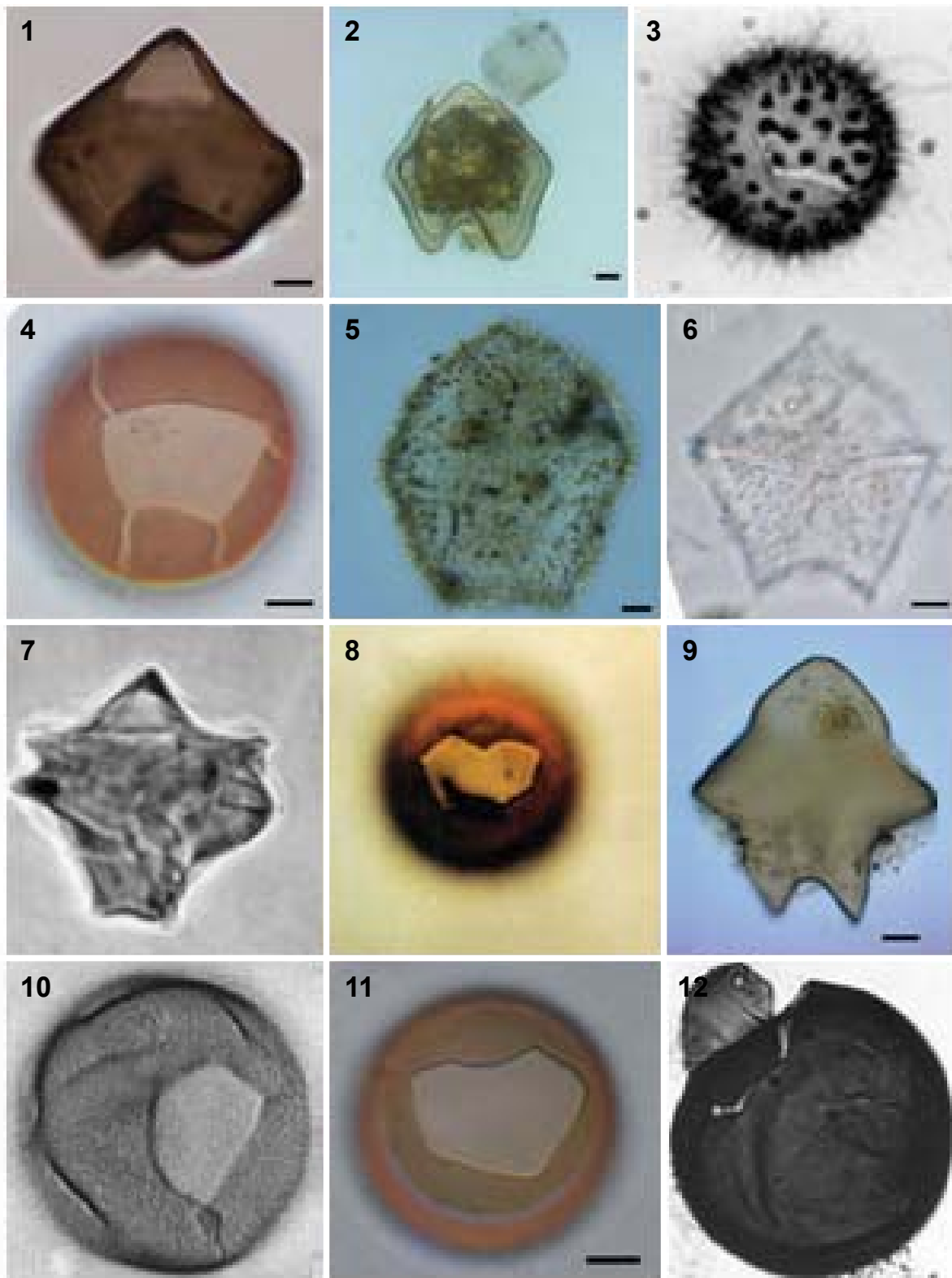
Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon *et al.* 1993; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2003; Kim *et al.* 2010)

*Protoperidinium minutum* (Kofoid) Loeblich III 1970

Paleontological name: cyst of *Protoperidinium minutum* (Kofoid) Loeblich III 1970 (Plate V-2)

Synonym: *Peridinium minutum* Kofoid 1907

Distribution: Jinhae-Masan bay (Kim 1991; Lee *et al.* 1998;



**Plate V.** Light microscope photographs of dinoflagellate cysts from Korean coastal waters. 1. *Quinquecuspis concreta*, 2. *Votadinium calvum*, 3. cyst of *Protoperidinium minutum*, 4. *Brigantedinium majusculum*, 5~6. *Trinovantedinium applanatum*, 7. *Selenopemphix alticinctum*, 8. cyst of *Protoperidinium thorianum*, 9. cyst of *Protoperidinium* sp., 10. *Brigantedinium auranteum*, 11. *Brigantedinium asymmetricum*, 12. *Brigantedinium grande*.



Park and Shim 2011), Tongyeong coasts (Kang *et al.* 1999; Park and Shim 2011), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeolja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Bokdol-bada (Shin *et al.* 2011)

*Protoperidinium oblongum* (Aurivillius) Parke et Dodge 1976

Paleontological name: *Votadinium calvum* Reid 1977 (Plate V-3)

Synonym: *Peridinium oblongum* Aurivillius 1898

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon *et al.* 1993; Lee *et al.* 1998; Park and Shim 2011), Tongyeong coasts (Kang *et al.* 1999; Pospelova and Kim 2010; Park and Shim 2011), Geoje coast (Shin *et al.* 2007), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeolja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Lee and Matsuoka 1996; Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), Yellow Sea (Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Kim *et al.* 2010)

*Protoperidinium petagonum* (Gran) Balech 1974

Paleontological name 1: *Brigantedinium majusculum* Reid 1977 ex Lentin et Williams 1993 (Plate V-4)

Synonym: *Peridinium petagonum* Gran 1902

*Protoperidinium expensum* Abe 1981

*P. parapetagonum* Wang 1936

*P. sinuosum* Lemmerman 1905

Distribution: Gamak bay (Shin *et al.* 2012), central South Sea (Cho *et al.* 2003), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2003)

Paleontological name 2: *Trinovantedinium applanatum* (Bradford 1977) Bujak et Davies 1983 (Plate V-5, 6)

Distribution: Gamak bay (Shin *et al.* 2011; Shin *et al.* 2012), Yeolja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Bokdol-bada (Shin *et al.* 2011)

Paleontological name 3: *Trinovantedinium capitatum* Reid 1977

Distribution: Busan harbor (Kim *et al.* 2005), Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon *et al.* 1993; Lee *et al.* 1998; Park and Shim 2011), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Shin *et al.* 2010b; Park and Shim 2011), Geoje coast (Shin *et al.* 2007), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park *et al.* 2004; Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2004; Kim *et al.* 2010)

Remarks: 유명세포의 한 종명에 다소 다른 형태를 나타내는 휴면세포, 시스트가 보고되고 있어, *Brigantedinium majusculum* (Baula *et al.* 2011), *Trinovantedinium applanatum* (Marrel and Zonneveld, 2003), *Trinovantedinium capitatum* (Baula *et al.* 2011) 등 다양한 고생물명(화석명)으로 표현되고 있음.

*Protoperidinium stellatum* (Wall) Balech 1994

Paleontological name: cyst of *Protoperidinium stellatum* (Wall in Wall et al. 1968) Rocho *et al.* 1999

Synonym: *Peridinium stellatum* Wall 1968

Distribution: Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Shin *et al.* 2010b; Shin *et al.* 2011; Shin *et al.* 2012), Yeolja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Tongyeong coasts (Pospelova and Kim 2010), Bokdol-bada (Shin *et al.* 2011), East China Sea (Cho and Matsuoka 2001)

*Protoperidinium subinerme* (Paulsen) Loeblich III 1970

Paleontological name: *Selenopemphix nephroides* (Benedek 1972) Benedek et Sarjeant 1981

*Selenopemphix alticinctum* (Bradford)

Matsuoka in Nehring 1997 (Plate V-7)

Synonym: *Peridinium subinerme* Paulsen 1904

Distribution: Jinhae-Masan bay (Moon *et al.* 1993; Lee and Matsuoka 1996; Lee *et al.* 1998), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Lee *et al.* 1999; Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeolja bay (Shin *et al.* 2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Kang *et al.* 1999; Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea

(Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2004; Kim *et al.* 2010)

*Protopteridinium thorianum* (Paulsen) Balech 1974

Paleontological name: cyst of *Protopteridinium thorianum* (Paulsen) Balech 1974 (Plate V-8)

Synonym: *Peridinium thorianum* Paulsen 1905

Distribution: Jinhae-Masan bay (Park and Shim 2011), Seamangeum coasts (Park and Shim 2011)

*Protopteridinium* spp.

Paleontological name: cyst of *Protopteridinium* sp./spp. (Plate V-9)

Distribution: Jinhae-Masan bay (Lee *et al.* 1998), Tongyeong coasts (Kang *et al.* 1999; Pospelova and Kim 2010), Gamak bay (Lee *et al.* 1999), central South Sea (Lee and Matsuoka 1996; Cho *et al.* 2003), Seamangeum coasts (Park *et al.* 2004), Yellow Sea (Hwang *et al.* 2009), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003)

*Protopteridinium* sp.

Paleontological name: *Brigantedinium auranteum* Reid 1977 (Plate V-10)

Distribution: East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001)

*Protopteridinium* sp.

Paleontological name: *Brigantedinium asymmetricum* Matsuoka 1987 (Plate V-11)

Distribution: Gamak bay (Shin *et al.* 2011), Yeoja bay (Shin *et al.* 2010a), Bokdol-bada (Shin *et al.* 2011)

*Protopteridinium* sp.

Paleontological name: *Brigantedinium grande* Matsuoka 1987 (Plate V-12)

Distribution: Gamak bay (Shin *et al.* 2012)

*Protopteridinium* spp.

Paleontological name: *Brigantedinium* sp. (Plate VI-1)

Distribution: Busan harbor (Kim *et al.* 2005), Gwangyang bay (Kim *et al.* 2003a, b), Gamak bay (Park and Yoon 2003; Park *et al.* 2004; Shin *et al.* 2010b; Park and Shim 2011; Shin *et al.* 2011; Shin *et al.* 2012), Yeoja bay (Shin *et al.*

2010a; Shin *et al.* 2011), Geoje coast (Shin *et al.* 2007), Tongyeong coasts (Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin *et al.* 2011), western South Sea (Shin *et al.* 2007), central South Sea (Cho *et al.* 2003; Park *et al.* 2005), Seamangeum coasts (Park and Shim 2011), Yellow Sea (Cho and Matsuoka 2001), East China Sea (Cho and Matsuoka 2001; Cho *et al.* 2001; Cho *et al.* 2003; Cho *et al.* 2004; Kim *et al.* 2010)

*Protopteridinium* sp.

Paleontological name: *Echinidinium aculenatum* Zonneveld 1997 (Plate VI-2)

Distribution: Gamak bay (Shin *et al.* 2010b), Yeoja bay (Shin *et al.* 2010a), Tongyeong coasts (Pospelova and Kim 2010)

*Protopteridinium* sp.

Paleontological name: *Echinidinium delicatum* Zonneveld 1997 (Plate VI-3)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Protopteridinium* sp.

Paleontological name: *Echinidinium* sp. cf. *delicatum* Zonneveld 1997 (Plate VI-4)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Protopteridinium* sp.

Paleontological name: *Echinidinium granulatum* Zonneveld 1997 (Plate VI-5)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Protopteridinium* spp.

Paleontological name: *Echinidinium* sp./spp. (Plate VI-6)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Protopteridinium* sp.

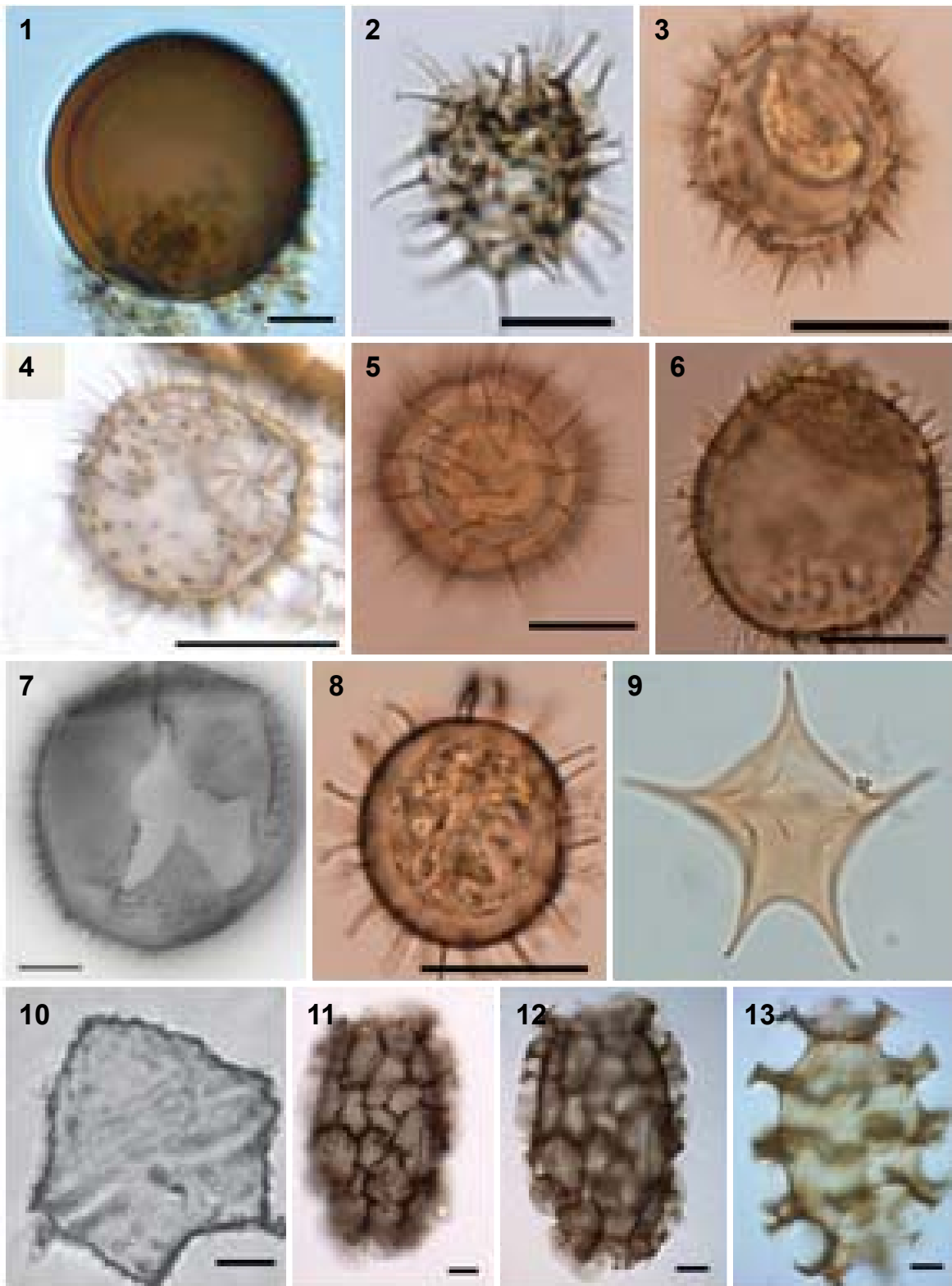
Paleontological name: *Islandinium brevispinosum* Pospelova et head 2002 (Plate VI-7)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Protopteridinium* sp.

Paleontological name: *Islandinium minutum* (Harland et Reid in Harland *et al.* 1980) Head *et al.* 2001 (Plate VI-8)

Distribution: Tongyeong coasts (Pospelova and Kim 2010)



**Plate VI.** Light microscope photographs of dinoflagellate cysts from Korean coastal waters. 1. *Brigantidium* sp. 2. *Echinidinium aculenatum*, 3. *Echinidinium delicatum*, 4. *Echinidinium* sp. cf. *delicatum*, 5. *Echinidinium granulatum*, 6. *Echinidinium* sp., 7. *Islandinium brevispinosum*, 8. *Islandinium minutum*, 9. *Stelladinium robustum*, 10. *Trinovantedinium pallidifulum*, 11~12. cyst of *Polykrikos kofoidii*, 13. cyst of *Polykrikos schwartzii*.

*Protoberidinium* sp.

Paleontological name: *Lejeunecysta aliva* (Reid 1977) Turon et Londeix 1988

Distribution: Tongyeong coasts (Pospelova and Kim 2010)

*Protoberidinium* sp.

Paleontological name: *Selenopemphix* sp.

Distribution: East China Sea (Cho and Matsuoka 2001; Cho et al. 2001)

*Protoberidinium* sp.

Paleontological name: *Stelladinium bifurcatum*

Distribution: East China Sea (Kim et al. 2010)

Remark: *Stelladinium bifurcatum*의 시스트 종명은 일부 학술지에 등장하지만, 원 출처는 확인이 되지 않음.

*Protoberidinium* sp.

Paleontological name: *Stelladinium robustum* Zonneveld 1997 (Plate VI-9)

Distribution: Busan harbor (Kim et al. 2005)

*Protoberidinium* sp.

Paleontological name: *Trinovantedinium pallidifulum* Matsuoka 1987 (Plate VI-10)

Distribution: Busan harbor (Kim et al. 2005), Gwangyang bay (Kim et al. 2003a), Gamak bay (Shin et al. 2010b; Shin et al. 2011), Yeoja bay (Shin et al. 2010a; Shin et al. 2011), Bokdol-bada (Shin et al. 2011), central South Sea (Cho et al. 2003)

**Order GYMNODINIALES Lemmerman 1910****Family GYMNODINIACEA Lankester 1885****(Gymnodinioid Group)****Genus *Polykrikos* Kofoid et Swezy 1921**

*Polykrikos kofoidii* Chatton 1914

Paleontological name: cyst of *Polykrikos kofoidii* Chatton 1914 (Plate VI-11, 12)

Distribution: Busan harbor (Kim et al. 2005), Jinhae-Masan bay (Kim 1991; Lee and Yoo 1991; Moon et al. 1993; Lee et al. 1998; Park and Shim 2011), Gwangyang bay (Kim et al. 2003a, b), Gamak bay (Lee et al. 1999; Park and Yoon 2003; Park et al. 2004; Park and Shim 2011; Shin et al. 2011; Shin et al. 2012), Yeoja bay (Shin et al. 2010a; Shin et al. 2011), Geoje coast (Shin et al. 2007), Tongyeong

coasts (Kang et al. 1999; Pospelova and Kim 2010; Park and Shim 2011), Bokdol-bada (Shin et al. 2011), western South Sea (Shin et al. 2007), central South Sea (Lee and Matsuoka 1996; Cho et al. 2003; Park et al. 2005), Seamangeum coasts (Park et al. 2004; Park and Shim 2011), East China Sea (Cho and Matsuoka 2001; Cho et al. 2001; Cho et al. 2004; Kim et al. 2010)

*Polykrikos schwartzii* Bütschli 1873

Paleontological name: cyst of *Polykrikos schwartzii* Bütschli 1873 (Plate VI-13)

Distribution: Busan harbor (Kim et al. 2005), Jinhae-Masan bay (Lee and Yoo 1991; Moon et al. 1993; Lee et al. 1998; Park and Shim 2011), Gwangyang bay (Kim et al. 2003a, b), Gamak bay (Lee et al. 1999; Park et al. 2004; Shin et al. 2010b; Shin et al. 2011; Shin et al. 2012), Yeoja bay (Shin et al. 2010a; Shin et al. 2011), Geoje coast (Shin et al. 2007), Tongyeong coasts (Kang et al. 1999; Pospelova and Kim 2010), Bokdol-bada (Shin et al. 2011), western South Sea (Shin et al. 2007), central South Sea (Cho et al. 2003; Park et al. 2005), East China Sea (Cho and Matsuoka 2001; Cho et al. 2001; Cho et al. 2004; Kim et al. 2010)

*Polykrikos* sp.

Paleontological name: cyst of *Polykrikos* sp.

Distribution: Jinhae-Masan bay (Kim 1991; Park and Shim 2011), Gamak bay (Shin et al. 2010b; Park and Shim 2011), Geoje coast (Shin et al. 2007), Tongyeong coasts (Park and Shim 2011), Seamangeum coasts (Park and Shim 2011), East China Sea (Cho et al. 2003; Kim et al. 2010)

**3. 한국주변해역의 외편모조류 시스트 출현 특성**

한국 연안 해역의 외편모조류 시스트이 우점 출현종과 시스트의 세포밀도를 Table 4에 정리하였다. 한국 연안 해역에서 *Gymnodinium catenatum*, *Scrippsiella trochoidea*, *Lingulodinium polyedrum*, *Alexandrium* spp. *Cochlodinium polykrikoides* 등과 같은 유해/유독 외편모조류는 특정 해역과 시기에 높은 세포밀도로 출현하여 적조를 형성하기도 하지만, 표층퇴적물에서 이들 시스트가 매우 높게 출현한다. 1995년 이후 반복적으로 가을에 남해 고힌과 남면, 소리도 사이의 붓돌바다와 여수해만에서 적조를 발생시키는 *C. polykrikoides*에 대해 아직도 종자군(seed population)으로서 역할은 분명하지 않지만 (Matsuoka et

**Table 4.** Abundance and dominant species of dinoflagellate cysts in the KCW

Study site	Abundance (cysts/g dry)	Dominant species	Reference
Busan harbour	210 ~ 869	<i>Gonyaulax</i> group/ <i>Spiniferites bulloideus</i>	Kim <i>et al.</i> 2005
Jinhae-Masan Bay	48 ~ 1,279*	<i>Protopteridinium</i> group	Lee and Yoo 1991
	627 ~ 5,026*	<i>Protopteridinium</i> group	Lee <i>et al.</i> 1998
Tongyeong coasts	130 ~ 2,165*	<i>Scrippsiella trochoidea</i>	Kang <i>et al.</i> 1999
	1,000 ~ 8,900	<i>Gonyaulax</i> group <i>Diplopsalis</i> group	Pospelova and Kim 2010
Geoje coasts	528 ~ 2,834	<i>Alexandrium affinis</i> <i>Alexandrium catenella/tamarensis</i> <i>Gonyaulax</i> group	Shin <i>et al.</i> 2007
Gwangyang Bay	115 ~ 2,188	<i>Spiniferites bulloideus</i> <i>Spiniferites delicatus</i> <i>Alexandrium</i> sp. (ellipsoid)	Kim <i>et al.</i> 2003a, b Kim <i>et al.</i> 2009
	226 ~ 1,365*	–	Lee <i>et al.</i> 1999
South Sea Gamak Bay	21 ~ 4,322	<i>Protopteridinium</i> group/ <i>Pt. americanum</i>	Park and Yoon 2003
	446 ~ 892	<i>Alexandrium affinis</i> <i>Alexandrium catenella/tamarensis</i> <i>Protopteridinium</i> cf. <i>minutum</i>	Shin <i>et al.</i> 2011
Yeoja Bay/Bokdol-bada	331 ~ 1,276	<i>Alexandrium affinis</i> <i>Alexandrium catenella/tamarensis</i> <i>Gonyulax</i> group	Shin <i>et al.</i> 2011
western parts	13 ~ 527	<i>Gonyulax</i> group <i>Protopteridinium</i> group	Shin <i>et al.</i> 2007 (?)
	16 ~ 1,501	<i>Spiniferites bulloideus</i> <i>Scrippsiella trochoidea</i>	Park <i>et al.</i> 2008
central parts	21 ~ 363*	<i>Gonyaulax</i> sp.	Lee and Matsuoka 1994
	184 ~ 2,600	<i>Alexandrium catenella/tamarensis</i> <i>Spiniferites bulloideus</i>	Cho <i>et al.</i> 2003
West Sea (Yellow Sea)	6 ~ 1,618	<i>Alexandrium catenella/tamarensis</i>	Park <i>et al.</i> 2004
	363 ~ 7,566	<i>Spiniferites bulloideus</i>	Cho and Matsuoka 2001
eastern parts	2 ~ 1,276	<i>Gonyulax</i> group <i>Protoceratium reticulatum</i>	Hwang <i>et al.</i> 2009
East China Sea	including Jeju off	<i>Spiniferites bulloideus</i>	Cho <i>et al.</i> 2004
	northern parts	<i>Spiniferites bulloideus</i>	Cho and Matsuoka 2001

\*marks is indicate cysts/cm<sup>3</sup> units

*al.* 2010), 시스트의 존재는 확실한 것으로 보고된다 (Pospelova and Kim 2010). 그리고 1986년에 부산 및 1996년 거제도에서 각각 2명의 사망자를 배출한 남해안의 마비성 패류독화 (Paralytic Shellfish Poisoning, PSP) 원인종으로 알려진 *Alexandrium tamarensis/catenella* type (Han *et al.* 1992)은 전 세계에서 아시아 해역에 특히 높은 세포 밀도를 보여 (Marret and Zonneveld 2003; Zonneveld *et al.*

2013), 동중국해를 중심으로 중국연안 (Wang *et al.* 2004) 과 한국 연안 해역 (Cho and Matsuoka 2001; Park *et al.* 2004; Shin *et al.* 2007)은 물론 일본 규슈서해안에 위치하는 아리케만에서도 우점 출현하는 것이 보고된다 (Shin, 2009). 국내에 유입되는 *A. tamarensis/catenella* type의 기원은 분명하지 않지만, 이들 종의 분포적 특징 (Zonneveld *et al.* 2013)으로부터 일본열도 남쪽에서 분기되어

동중국해와 서일본 그리고 한국 연안 해역에 영향을 미치는 쓰시마난류와 밀접한 관련성 (Teague *et al.* 2003)을 보이는 것으로 추정되며, 진해-마산만 주변 해역은 *A. tamarense* 시스트의 집적과 발아, 그리고 유영세포의 성장에 좋은 환경 조건을 가지는 것으로 추정하고 있다 (Shin *et al.* 2007). 또한 탄산염의 세포벽은 가지는 *Scrippsiella trocoides* 또한 한국 남해안에 우점 출현하고 있을 뿐만 아니라 (Kang *et al.* 1999; Park *et al.* 2005, 2008), 해저 무산소화와 관련하여 해저환경의 pH 농도 변화에 따라 형태를 달리하는 것이 보고되고 있다 (Shin *et al.* 2013).

외편모조류 시스트 세포밀도는 적게는 개방된 외해에서 관찰이 되지 않은 정점도 있지만, 부영양화가 진행된 진해만 (Lee *et al.* 1998)이나 통영 연안 (Pospelova and Kim 2010)에서는 10,000 cysts/g dry 수준의 높은 세포밀도를 보여, 해역에 따른 변화 폭이 크게 나타난다 (Table 4). 종별로는 Gonyaulacoid 그룹과 Protoperidinioid 그룹의 *Spiniferites*속과 *Brigantidium*속의 종이 비교적 높은 밀도로 출현하나 해역에 따라 다소 다른 양상을 보인다. 일례로 가막만과 진해-마산만은 *Brigantidium*속과 *Protoperidinium*속 같은 중속영양종이 많이 출현하는 반면에 (Lee *et al.* 1998; Park and Yoon 2003; Shin 2009), 광양만이나 거제도 연안에서는 *Spiniferites*속의 *S. bulloideus*와 *Alexandrium*속 등의 독립영양종이 많이 출현하였다 (Kim *et al.* 2003a, b; Shin *et al.* 2007). 이와 같은 차이는 시스트가 퇴적되는 퇴적물의 입도조성 (Dale 1983)과 외편모조류 유영세포 서식환경의 차이를 나타내는 것으로 판단된다 (Smyda and Reynolds 2003). 즉 시스트는 미세한 세립질 퇴적물이 관찰되는 해역에서 높은 밀도를 보여, 펄 함량이 높은 남해 중앙부 해역보다 비교적 펄 함량이 낮은 진도, 완도가 위치한 남서연안에서 낮은 밀도로 관찰 된다 (Shin *et al.* 2007). 시스트 분포는 이들 환경인자 이외에 수온, 광량, 염분, 영양염류, 그리고 용존산소와 같은 물리·화학적 환경인자 및 식물플랑크톤의 생물량과 세균의 활성도와 같은 생물학적 인자와도 밀접한 관련성을 보인다 (Lee *et al.* 1998; Lee *et al.* 1999; Park and Yoon 2003; 서론 내용 참조).

## 적 요

한국 연안 해역의 외편모조류 시스트의 연구 현황과 특성을 파악하기 위해 한국 연안과 내만은 물론 제주도 남부와 황해 일부해역을 포함한 동중국해를 대상으로 수행한 45편의 학술연구논문을 분석하였다. 결과 한국의

외편모조류 시스트는 1980년대 후반부터 연구가 시작되었고, 대상 해역은 적조발생 등 부영양화 해역이나 연안 개발이 이루어지는 해역에 집중되었으며, 동해를 대상으로 한 연구결과는 없었다. 연구 내용도 단순한 출현 종 분석에서 부영양화 진행 등 해양환경의 변화과정 추적, 적조 발생에서 종자군으로서 역할, 세디먼트 트랩을 이용한 시스트의 형성과 변화양상 추적, 수소이온 농도 등 해양환경 변화에 따른 형태변화, 실험실에서 특정 종의 발아 특성 등 국제적 수준의 다양한 연구가 진행되고 있었다. 출현종이나 출현 세포밀도 역시 해역에 따라 매우 다양한 특성을 보인다. 그러나 한국의 외편모조류 시스트 연구는 아직 체계적 연구가 이루어지지 못하고 있고, 단편적이면서 개별적 내용으로 매우 제한적인 연구 성격을 나타내었다. 특정 해역에 편중된 연구결과와 특정 연구 연구 집단에 의해 산발적인 연구가 수행되는 경향을 나타내었다. 해양에서 표층퇴적물의 외편모조류 시스트는 표영 환경의 누적지표를 나타내는 것으로 해양환경 변화를 효율적으로 추적하는 데 유용한 지표가 되고 있음을 고려할 때, 국내에서도 조직적인 인력양성과 함께 해양생태계의 구성인자로서 필수 해양생물 분야로 취급하는 연계적인 연구 추진이 절실하게 요구된다.

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