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Seasonal Variations in Water Temperature and Salinity and Phytoplankton Abundance in Terms of Oyster and Squirt Fisheries in the East Sea

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Water temperature, salinity, transparency and phytoplankton in the eastern Korean coastal waters in May, August and October during the period of 2007-2010 were determinded. 12 offshore sites; Gangneung, Donghae, Samcheok, Imwon, Jubyun, Hupo, Chuksan, Ganggu, Wolpo, Pohang, Guryongpo and Gampo. Water temperature in the sea surface varied from 14°C to 16°C, 18°C to 25°C, 22°C to 23°C in May, August and October, but bottom water temperature had a significant fluctuation at different regions and each year. Unlike water temperature, salinity did not show significantly fluctuations. The temporal variations of the transparency did not show a great fluctuation. *Chaetoceros* spp., *Leptocylindrus danicus* and *Pseudonitzschia pungens* were most abundance phytoplankton species in the eastern coastal waters.

Key words: East Sea, fluctuation, water temperature, bottom water, phytoplankton

Introduction

The East Sea is a marginal sea enclosed by the Korean, Japanese and Russian territory in the northwestern region of the Pacific Ocean. The embayment hollow in the north-eastern region of the Pacific is separated by shallow sills of the stratits. In addition, the Tsushima current, a branch of the Kuroshio, brings subtropical waters from the East China Sea. The East Sea has a limited exchange of sea water with the North Pacific Ocean because of the sill depth of ≤150 m. The oyster (*Crassostre gigas*) and seq squirt (*Halocynthia roretzi*) have successfully cultured in the offshore of the eastern coast for many decades[1-2]. The oyster and sea squirt live in shallow water, usually attached to rocks and artificial structures. A recent study suggests that the East Sea is undergoing greatly changes in deep water caused by global warming[3,9-11]. Therefore, it is very important to monitor seasonal variations of water temperature and salinity and phytoplankton species composition because phytoplanktons are food organisms for aquacultured oyster and sea squirt, and phytoplankton growth and species composition depend on the water temperature and salinity. Furthermore, harmful dinoflagellate *Cochlodinium polykrikoides* occurred in 1995, 2001, 2002 and 2003 in the East Sea (www.nfrdi.kr). Monitoring of HABs (Harmful Algal Bloom) was useful to reduce the economic loss in aquaculture fisheries. The purpose of this work is to report inter-annual variability of water temperature and salinity off the eastern coast where oyster and sea squirt farming activities are extensive.

Materials and Methods

Samplings and surveys were performed at 12 areas that are Gangneung (37.43°N, 129.2°E, 77 m in water depth), Donghae (37.25°N, 129.9°E, 28 m in water depth), Samcheok (37.25°N, 129.12°E, 20 m in water depth), Imwon (37.14°N, 129.22°E, 50 m in water depth), Jubyun (37.5°N, 129.23°E, 33 m in water depth), Hupo (36.41°N, 129.29°E, 32 m in water depth),

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Chuksan (36.32°N, 129.29°E, 41 m in water depth), Ganggu (36.21°N, 129.23°E, 28 m in water depth), Wolpo (36.12°N, 129.24°E, 28 m in water depth), Pohang (36.3°N, 129.30°E, 12 m in water depth), Guryongpo (35.59°N, 129.35°E, 32 m in water depth) and Gampo (35.42°N, 129.29°E, 43 m in water depth). Sea water temperature and salinity were measured using a thermistor and conductivity (YSI 6920) in May, August and October for years (2007-2010). Transparency of sea water was measured. Samples for phytoplankton identification were fixed with Lugol's solution and counted on Sedgwick-Rafter under the light microscope (Olympus, BX50) in the shore laboratory.

Results and Discussion

Water temperature

In May, the fluctuation of water temperature on the surface varied from 14°C to 16°C in 2007 regardless of sampling sites (Fig. 1). This range between 14°C and 16°C continuously maintained in 2008 and 2009, but in 2010 the sea surface temperature was lower as much as 2°C compared with 2007, 2008 and 2009. The sea surface temperature in the offshore regions between Gangneung through Chuksan was about 12°C, whereas

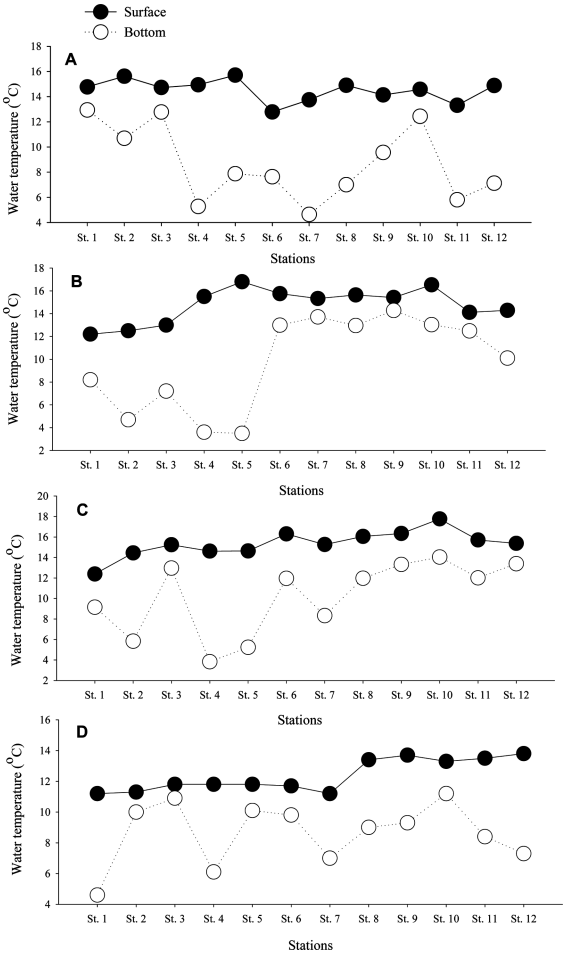

Fig. 1. Surface and bottom water temperature in eastern coastal waters in May. A, 2007; B, 2008; C, 2009; D, 2010. St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo.

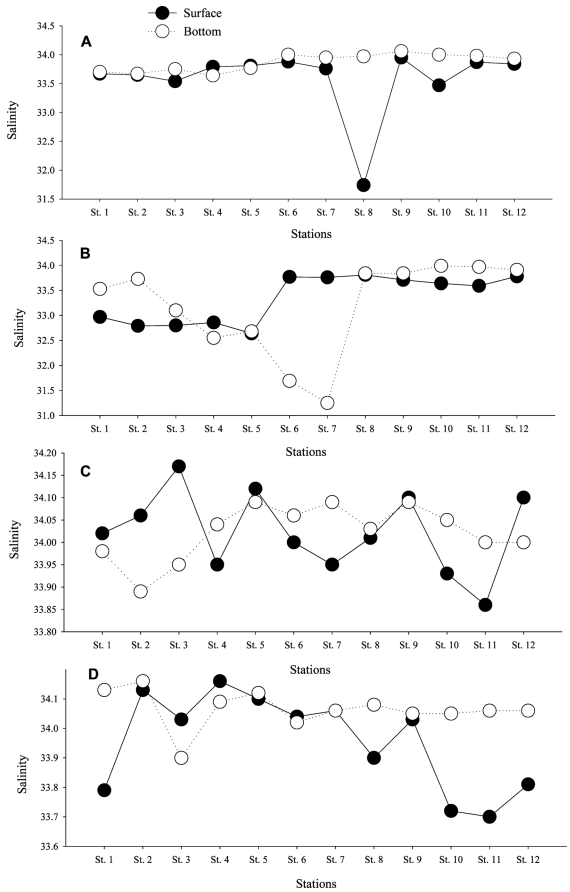

Fig. 2. Surface and bottom salinity in eastern coastal waters in May. A, 2007; B, 2008; C, 2009; D, 2010. St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo.

in the southern areas of Chuksan (Gangu, Wolpo, Pohang, Guryongpo and Gampo) was approximately 2°C higher than previous years of 2008 and 2009. The curve of bottom water temperature had a great fluctuation according to sampling sites and elapsed years compared with the fluctuation of surface water temperature. In 2007, most sites showed below 10°C except for Gangneung, Donghae, Samcheok and Pohang. In 2008, Gangneung, Donghae, Samcheok, Imwon and Jubyun showed cold water temperatures of below 10°C, but between Hupo through Gampo were extremely higher temperature that had three times compared with Jubyun and Wolpo. In particular, Imwon was the lowest water temperature of ≤6°C during the period of 2007-2010. Consequently, the bottom layer in eastern coastal waters fluctuated more greatly in water temperature than that of the surface depending on sampling sites[4-5].

Salinity

Salinity in surface was a similar to the surface in 2007-2010, although Chuksan and Gangju showed the lowest bottom and surface salinity of approximately 31 in 2008 and 2007 (Fig. 2). In August, surface water temperature in 2007 ranged from 20°C to 22°C, but Samcheok/Imwon/Jubyun showed lower water temperature of approximately 16°C, 18°C and 14°C, respectively (Fig. 3). In 2007, surface salinity ranged from 32 to 33 which were not greatly changed depending on sampling sites. Bottom layer was higher value of

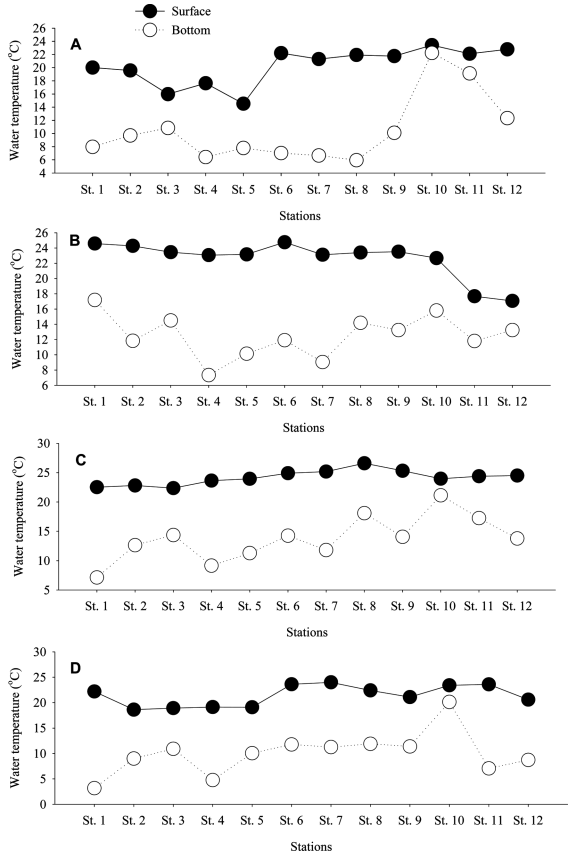

Fig. 3. Surface and bottom water temperature in eastern coastal waters in August. A, 2007; B, 2008; C, 2009; D, 2010. St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo.

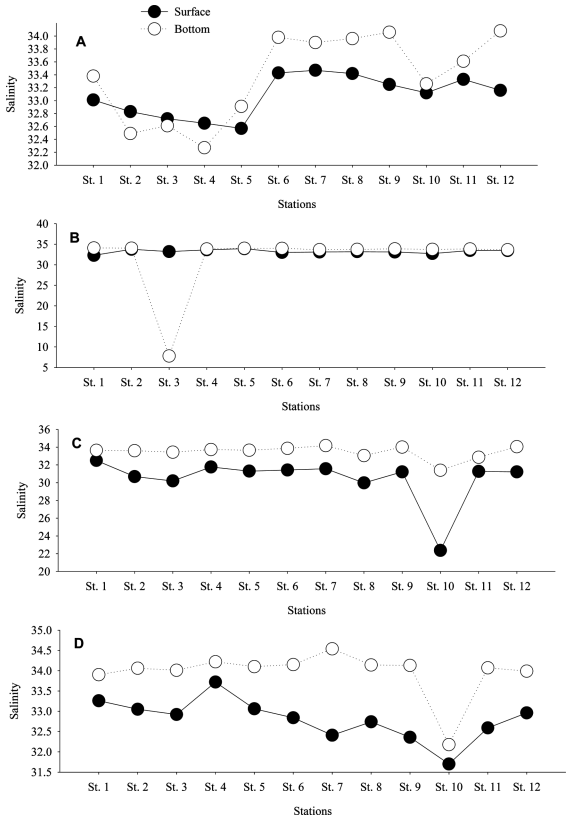

Fig. 4. Surface and bottom salinity in eastern coastal waters in August. A, 2007; B, 2008; C, 2009; D, 2010. St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo.

salinity with above 0.5 than that of surface, which was similar to 2008, 2009 and 2010 (Fig. 4). Salinity in eastern coastal waters had a similar range regardless of sampling sites, but Samcheok in 2008 and Pohang in 2009 showed extremely lower value of salinity. It is thought that Samcheok and Pohang have shallow water depth compared with other sampling sites and are much influenced by fresh water from landmasses. In October, surface water temperature in 2007 and 2008 ranged from 22°C to 23°C, but 2009 and 2010 had lower water temperature of approximately 2°C (Fig. 5). The fluctuation of salinity in October was similar to August that the bottom layer was higher value of salinity than that of surface (Fig. 6). Surface salinity in Pohang was the lowest value of 29, 30, 32 in 2007, 2008 and 2010, respectively. Compared to August, salinity in October did not show significantly lower value of below 20.

Transparency

Transparency has a high resolution of discriminating the water mass characteristics compared with temperature and has an important role in determining water front[6]. The temporal variations of the transparency did not show a great fluctuation according to May, August and October, with range of 4-16 m (Fig. 7). Pohang, Guryongpo and Gampo appeared to be lower transpar-

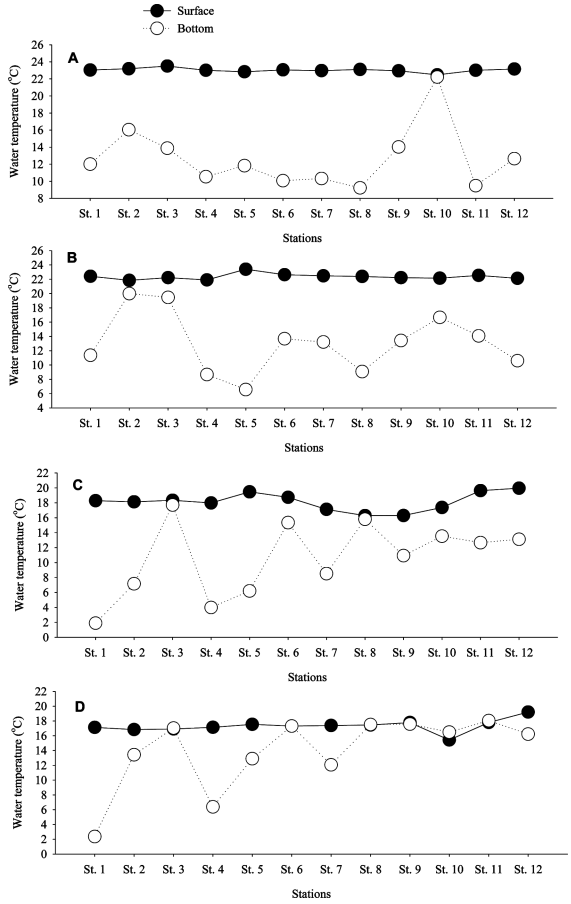

Fig. 5. Surface and bottom water temperature in eastern coastal waters in October. A, 2007; B, 2008; C, 2009; D, 2010. St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo.

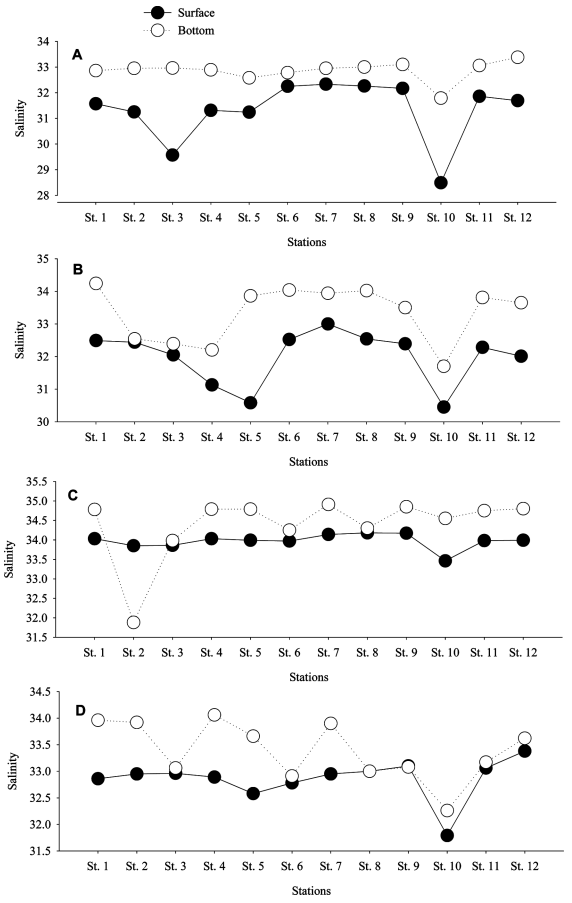

Fig. 6. Surface and bottom salinity in eastern coastal waters in October. A, 2007; B, 2008; C, 2009; D, 2010. St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo.

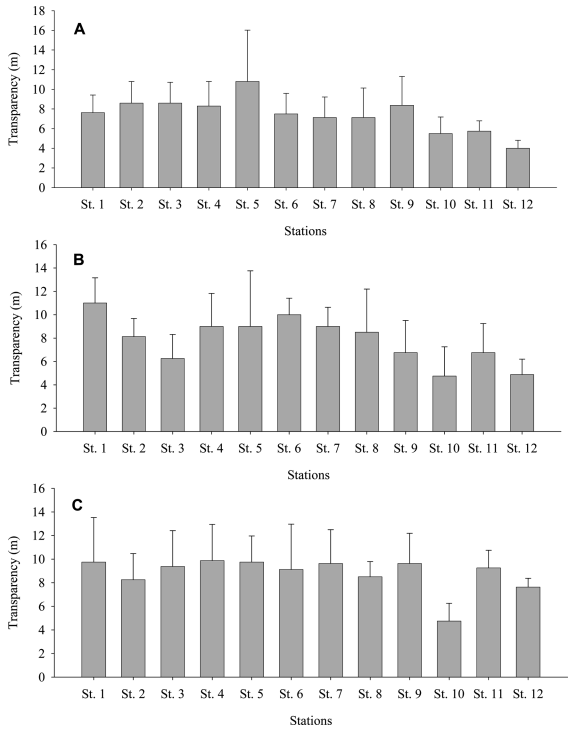

Fig. 7. Transparency in May (A), August (B) and October (C) in eastern coastal waters. St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo.

ency compared with other sampling sites. These regions except for Pohang/Guryongpo/Gampo showed higher transparency of above 6 m.

Phytoplankton

The dominant species in May, August and October. *Chaetoceros* spp., *Leptocylindrus danicus* and *Pseudonitzschia pungens* were the highest number of dominant phytoplankton, which were regarded as main species in the East Sea (Table 1). The composition of phytoplankton in the East Sea appears to exhibit a simple assemblage instead of variable species such as the South Sea[7-8].

Conclusion

In conclusion, eastern coastal waters are shown in seasonal and yearly fluctuations. In particular, bottom water temperature has a great variation compared with surface water temperature. For sustainable and continuous production of aquaculture on the bottom, real-time surveillance and monitoring are needed in future.

Table 1. Dominant species in May, August and October occurring in the East Sea during the period of 2007-2010

Region	May				August				October			
	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
St. 1	Ld (8)	Ca (73)	Ca (8)	Cp (22) Pp (22)	La (2)	Nd (123)	Ca (5)	Nd (6)	Tf (5)	Rsp (11)	Pp (4)	Csp (9)
St. 2	Cp (4)	Ca (106)	Ca (5)	Cp (106) Pp (106)	Mr (9)	Nd (7)	Ld (20)	Ld (11)	Rs (3)	Rsp (12)	Pp (23)	Pp (5)
St. 3	Cp (3)	Ca (17)	Ca (5)	Cp (10) Pp (10)	Ld (13)	Nd (17)	Ld (64) Nd (64)	Ld (6)	Ld (6)	Pp (16) Rsp (16)	Pp (7)	Pp (5)
St. 4	Pp (4)	Ca (14)	Ca (7)	Pp (66) Tn (66)	Ld (3)	Nd (5)	Ld (9) Nd (9)	Pp (29) Rs (29)	Tf (5)	Pp (19) Rsp (19)	Pp (5)	Pp (9)
St. 5	Pp (4)	Ca (32) Ld (22)	Ca (4)	Pp (69) Tn (69)	Ld (4)	Nd (12)	Ld (25) Nd (25)	Ca (3)	Tf (12)	Rsp (6)	Pp (4)	Pp (7)

Note: St. 1; Gangneung, St. 2; Donghae, St. 3; Samcheok, St. 4; Imwon, St. 5; Jubyun, St. 6; Hupo, St. 7; Chuksan, St. 8; Ganggu, St. 9; Wolpo, St. 10; Pohang, St. 11; Guryongpo, St. 12; Gampo. Parensis means the number of cells (cells ml^{-1}). Ld; *Leptocylindrus danicus*, Cp; *Chaetoceros pseudocurvisetus*, Pp; *Pseudonitzschia pungens*, St; *Scripsiella trochoidea*, Ca; *Chaetoceros affine*, Ld; *Leptocylindrus danicus*, Tf; *Thalassiothrix fraudelli*i, Ts; *Thalassiosira* sp., Eg; *Euteptiella gymnastica*, Tn; *Thalassionema nitzchiodes*, Rs; *Rhizosolenia setigera*, Mr; *Mesodinium ruburum*, Csp; *Chaetoceros* spp., Gf; *Guinardia flaccida*, Cf; *Ceratium furca*, Cs; *Chaetoceros* sp., Nd; *Nitzschia delicatassima*, Pt; *Prorocentrum triestium*, Rst; *Rhizosolenia stotterforth*ii, Ba; *Bidulphia aurita*, Ag; *Asterionella gracille*, Rsp; *Rhizosolenia* spp.

Table 1. Continued

Region	May				August				October			
	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
St. 6	Cp (7)	Ld (187) Pp (187)	Ld (248)	Pp (96) Cp (96)	Ld (5)	Pt (23) Ca (23)	Ld (16) Nd (16)	Rs (11)	Rf (15)	Rsp (6)	Ag (442) Pp (442)	Pp (5)
St. 7	Pp (6)	Ld (278) Pp (278)	Ld (134)	Pp (49) Tn (49)	Ld (3)	Ca (10)	St (54)	Rs (18)	Rf (6)	Rsp (5)	Pp (53)	Ld (3)
St. 8	Ca (7)	Ld (347) Pp (347)	Ld (119)	Pp (186) Rs (186)	Ca (4)	Ca (7)	Ca (64) Pp (64)	Rs (15) Rst (15)	Ld 915)	Rsp (6)	Pp (6)	Pp (2)
St. 9	St (14)	Ld (199) Pp (199)	Ld (22) Pp (22)	Pp (59) Rs (59)	Csp (5)	Ca (8)	Tn (33)	Rs (46) Rst (46)	Ba (26) Gf (26)	Rsp (16)	Pp (5)	Pp (5)
St. 10	Ca (17) Ld (17)	Ld (288) Pp (288)	Ld (27)	Cp (54) Tn (54)	Gf (11)	Nd (77) Ca (77)	Ca (156) Tn (156)	Rst (312)	Ld (23)	Ag (19)	Tf (68) Cs (68)	Csp (1083)
St. 11	Tf (5)	Cp (95) Pp (95)	Ld (184)	Cp (36) Tn (36)	Cf (5)	Ca (19)	Pp (54) Tn (54)	Pp (57) Tn (57)	Ld (3)	Rsp (4)	Pp (47)	Csp (26)
St. 12	Ca (8) Tf (8)	Ts (126)	Eg (18)	Cp (45) Pp (45)	Cs (3)	Ca (5)	Ca (53) Tn (53)	Pp (77) Tn (77)	Gf (16)	Rsp (23)	Pp (192)	Pp (8)

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