

R/V Kaiyo-Mar CRUISE REPORT

KY1305

25 October, 2013 – 10 January, 2014

(Tokyo – Honolulu – Tokyo)

**Report of the research on the Spawning stock and paralarvae of
the neon flying squid *Ommastrephes bartramii* in the North Pacific**

1 Cruise date:

(Leg 1) 25 October, 2013 – 23 November, 2013 (Tokyo – Honolulu)

(Leg 2) 27 November, 2013 – 24 December, 2013 (Honolulu –Honolulu)

(Return) 28 December, 2013 – 10 January, 2014 (Honolulu – Tokyo)

2 Chief Scientist in charge of the project

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4 Research vessel

Name: Kaiyo-Mar

Flag state: Japan

Owner: Fisheries Agency, Government of Japan

Operator: Fisheries Agency, Government of Japan

Overall length (meters): 93.01 m

Maximum draught (meters): 6.0 m

Gross tonnage: 2,942 tons

5 Areas of Operations:

North Pacific region between latitudes 28°-37°N and longitudes 157°E-177°W, and the Northern Hawaii region between latitudes 24°-33°N and longitudes 155°-173°W (Fig. 1). Most of these areas overlap with the subtropical frontal zone (STFZ) and the Transition Zone Chlorophyll Front (TZCF) in the winter north Pacific.

The cruise comprised two legs.

Leg-1: During leg 1, the cruise surveyed the North Pacific in the region between latitudes 28°-37°N and longitudes 157°E-177°W. The cruise consisted 32 stations, performed in five longitudinal sections. Each station consisted of CTD¹ and XCTD² observations, hand jigging, NORPAC³ net sampling, 2m ring net sampling, Nackthai net⁴ sampling and FluoroProbe⁵ observations. MOCNESS⁶ and Bongo net⁷ sampling were conducted at few stations based on the 2 m ring net⁸ catch of *O. bartramii* paralarvae. XCTD observations were done halfway between stations along every longitudinal section.

Leg-2: During leg 2 the cruise surveyed the Northern Hawaii region between latitudes 24°-33°N and longitudes 155°-173°W. The cruise consisted 49 stations, performed in seven longitudinal sections. Observations were similar to leg 1. In addition artificial fertilization experiments were conducted on board.

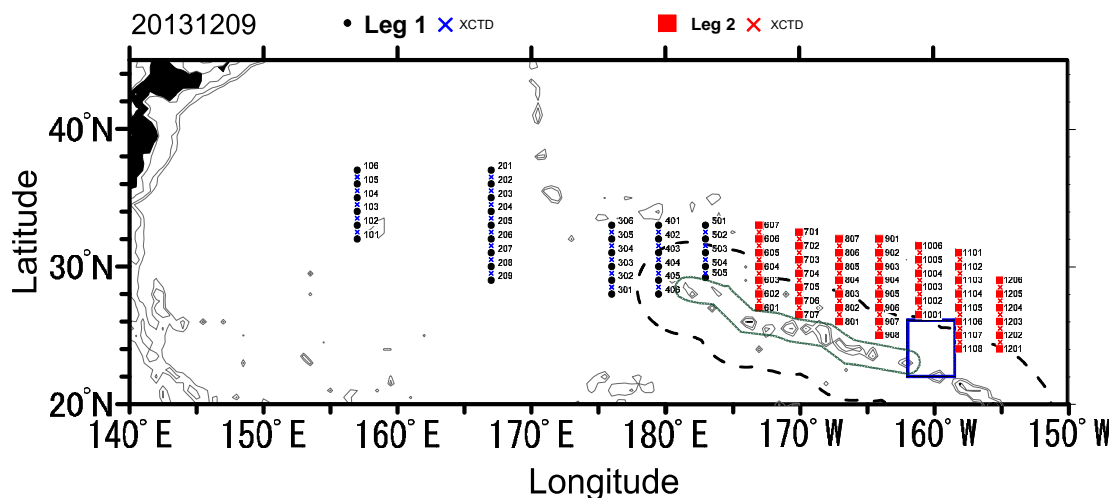


Fig.1 Cruise area and research stations of KY1305 (Leg1 black circles ● and XCTD X; Leg2 red squares ■ and XCTD x). Black broken line indicate the US EEZ, green enclosed area is Papahānaumokuākea Marine National Monument (PMNM) and blue rectangular is a US missile test area.

¹ CTD: An oceanography instrument used to determine the conductivity, temperature, and depth of the ocean.

² XCTD: expendable CTD

³ NORPAC net of mouth diameter 45cm, length 180cm and 0.335mm mesh, equipped with flow meter

⁴ Nackthai net of 20 cm mouth diameter and 0.335 mm mesh, equipped with Hydro Bios flow meter

⁵ FluoroProbe: A highly sensitive measuring instrument for the analysis of chlorophyll with algae class determination.

⁶ Multiple opening / closing net and environmental sensing system of 1 m² mouth opening with 0.335 mm mesh

⁷ Bongo net of 70 cm mouth diameter and 0.335 mm mesh, equipped with Hydro Bios flow meter

⁸ Ring net of 2 m mouth diameter and 526 μm

6 Research results:

6.1 Nature and objectives of the project:

The autumn cohort stock of neon flying squid *Ommastrephes bartramii* in the North Pacific Ocean is an important target resource for the Japanese pelagic jigging fishery. Its North Pacific population comprises two cohorts (autumn and winter-spring). The population undergoes a large-scale seasonal north-south migration. Spawning grounds of autumn cohort occur in subtropical frontal zone (STFZ) where the sea surface temperature (SST) ranges 21-25 °C, and feeding grounds occur in northern waters near the Subarctic Boundary. *O. bartramii* matures at 7-10 months and has an estimated one-year lifespan.⁹

Last two decades witnessed a decrease in squid landing and the amount of catch was fluctuating. The reason could be the influence of oceanographic conditions, particularly the movement of Transition Zone Chlorophyll Front (TZCF) in the Pacific Ocean.^{10,11} The stock is subject to management plans of the North Pacific Fisheries Commission (NPFC), so fishery independent data obtained from research vessels are required to perform a stock assessment in order to sustainably manage the resource. In November-December 2013, the R/V Kaiyo Maru carried out a research cruise to develop a new method to assess the spawning escapement biomass derived from abundance of paralarvae¹² as a proxy of spawning stock biomass. The cruise aimed to confirm spawning grounds in three areas – west (155°-165°E), Midway (175°E -175°W) and northern Hawaiian Islands (170°-155°W) – by collecting spawning squid and paralarvae. Oceanographic properties closely related to the spawning habitat and paralarval survival were also monitored. Artificial fertilization experiments were done to obtain *O. bartramii* paralarvae to compare the survival and behavioral characteristics with the collected wild paralarvae. During the expedition, we had the following specific targets to be investigated.

- (1) Sampling of squid by hand jigging
- (2) Sampling of paralarvae using plankton and larvae nets (NORPAC net, Ring net of 2 m mouth diameter, Nackthai net, MOCNESS, Bongo net)
- (3) Collection of oceanographic data by CTD and XCTD survey and chlorophyll-a analysis
- (4) Identification of ommastrephid paralarvae on board by mtDNA¹³ analysis
- (5) Artificial fertilization and rearing of hatchlings

Outline of observations made during the cruise are shown in Table 1(Leg 1) and Table 2 (Leg 2).

⁹ Bower, J. R., & Ichii, T. (2005). The red flying squid (*Ommastrephes bartramii*): A review of recent research and the fishery in Japan. Fisheries Research, 76(1), 39–55.

¹⁰ Ichii, T., Mahapatra, K., Sakai, M., Wakabayashi, T., Okamura, H., Igarashi, H., ... Okada, Y. (2011). Changes in abundance of the neon flying squid *Ommastrephes bartramii* in relation to climate change in the central North Pacific Ocean. Marine Ecology Progress Series, 441, 151–164.

¹¹ Polovina, J. ., Howell, E., Kobayashi, D., & Seki, M. (2001). The Transition Zone Chlorophyll Front, a dynamic, global feature defining migration and forage habitat for marine resources. Progress in Oceanography, 49, 469–483.

¹² Paralarva: Larval cephalopods in the planktonic stages between hatchling and sub-adult.

¹³ mtDNA: Mitochondrial DNA

Table 1-1. Outline of observation in KY1305 Leg 1.

Sta.	Ship time		Start Ob		Bottom depth (m)	Observation items							
	Date	Time	Lat	Long		XCTD	CTD (Water sample)	Jigging squid	NORPAC net	Nackthai net	Fluoro Probe	2m ring net	other
St-CAL1	2013/10/27	10:39 ~ 11:06	35-09.56 N	139-44.59 E	392								calibration
St-101	2013/10/30	01:55 ~ 05:05	31-59.99 N	157-00.10 E	3,552		•	•	•	•	•	•	
St-101X	2013/10/30	07:43 ~ 07:52	32-33.73 N	157-00.16 E	3,396	•							
St-102	2013/10/30	09:35 ~ 11:25	32-59.76 N	156-59.90 E	4,637		•		•	•	•	•	
St-102X	2013/10/30	13:28 ~ 13:35	33-30.00 N	156-59.00 E	5,050	•							
St-103	2013/10/30	16:00 ~ 19:00	34-00.08 N	157-00.03 E	5,294		•	•	•	•	•	•	
St-103X	2013/10/31	02:35 ~ 02:36	34-30.27 N	156-55.85 E	5,283	•							
St-104	2013/11/01	21:59 ~ 01:55	35-00.01 N	157-00.07 W	5,000		•	•	•	•	•	•	
St-104X	2013/11/01	05:59 ~ 06:06	35-29.95 N	157-00.33 E	4,937	•							
St-105	2013/11/01	09:00 ~ 10:55	35-59.77 N	156-59.99 E	4,385		•		•	•	•	•	
St-105X	2013/11/01	13:37 ~ 13:56	36-29.99 N	157-00.70 E	6,056	•							
St-106	2013/11/01	16:24 ~ 19:26	37-00.07 N	156-59.91 E	4,203		•	•	•	•	•	•	
St-201	2013/11/03	15:55 ~ 19:00	37-00.06 N	167-00.02 E	4,916		•	•	•	•	•	•	
St-201X	2013/11/03	21:30 ~ 21:36	36-30.09 N	166-59.99 E	5,260	•							
St-202	2013/11/04	00:00 ~ 02:55	35-59.98 N	166-59.99 E	5,510		•	•	•	•	•	•	
St-202X	2013/11/04	05:22 ~ 05:29	35-30.09 N	167-00.03 E	5,357	•							
St-203	2013/11/04	08:27 ~ 10:00	34-59.90 N	167-00.05 E	5,534		•		•	•	•	•	
St-203X	2013/11/04	12:43 ~ 12:46	34-30.07 N	166-59.96 E	5,877	•							
St-204	2013/11/04	15:53 ~ 19:06	34-00.00 N	167-00.01 E	5,955		•	•	•	•	•	•	
St-204X	2013/11/04	21:18 ~ 21:24	33-30.03 N	167-00.02 E	5,853	•							
St-205	2013/11/05	00:00 ~ 02:42	32-59.92 N	167-00.03 E	6,010		•	•	•	•	•	•	
St-205X	2013/11/05	05:20 ~ 05:51	32-30.11 N	167-01.42 E	6,052	•							
St-206	2013/11/05	08:30 ~ 10:03	32-00.04 N	166-59.96 E	6,037		•		•	•	•	•	
St-206X	2013/11/05	13:05 ~ 13:11	31-30.04 N	166-59.96 E	5,962	•							
St-207	2013/11/05	16:17 ~ 19:01	31-00.07 N	167-00.06 E	5,980		•	•	•	•	•	•	
St-207X	2013/11/05	21:36 ~ 21:42	30-30.07 N	167-00.00 E	5,991	•							
St-208	2013/11/06	00:00 ~ 02:45	29-59.87 N	167-00.00 E	5,993		•	•	•	•	•	•	
St-208X	2013/11/06	05:27 ~ 05:34	29-30.00 N	167-00.01 E	5,699	•							
St-209	2013/11/06	08:25 ~ 10:02	28-59.98 N	166-59.96 E	5,714		•		•	•	•	•	
St-Argo-1	2013/11/07	11:58 ~ 12:00	28-15.85 N	173-37.82 E	5,791								Argo float
St-Argo-2	2013/11/07	23:43 ~ 23:44	28-00.04 N	175-59.62 E	5,444								Argo float
St-301	2013/11/08	00:00 ~ 02:53	28-00.04 N	175-59.95 E	5,447		•	•	•	•	•	•	
St-301X	2013/11/08	05:27 ~ 05:35	28-29.02 N	176-00.63 E	4,388	•							
St-302	2013/11/08	08:25 ~ 10:15	29-00.07 N	175-59.98 E	5,118		•		•	•	•	•	
St-302X	2013/11/08	13:02 ~ 13:08	29-29.95 N	175-58.58 E	5,106	•							
St-303	2013/11/08	16:15 ~ 19:15	30-00.00 N	176-00.07 E	5,240		•	•	•	•	•	•	Water sample
St-303X	2013/11/08	21:37 ~ 21:43	30-29.97 N	176-00.00 E	5,363	•							
St-304	2013/11/09	00:00 ~ 03:00	30-59.99 N	176-00.04 E	3,141			•	•	•	•	•	Water sample
St-304X	2013/11/09	05:44 ~ 05:51	31-29.72 N	176-00.17 E	5,337	•							
St-305	2013/11/09	08:55 ~ 10:37	32-00.06 N	175-59.95 E	5,434		•		•	•	•	•	
St-305X	2013/11/09	13:09 ~ 13:15	32-30.01 N	175-59.75 E	5,405	•							
St-306	2013/11/09	16:00 ~ 19:00	33-00.09 N	176-00.00 E	3,863		•	•	•	•	•	•	
St-401	2013/11/10	16:12 ~ 19:04	32-59.97 N	179-29.92 E	4,874		•	•	•	•	•	•	
St-401X	2013/11/10	21:30 ~ 21:36	32-30.02 N	179-30.67 E	5,339	•							
St-402	2013/11/11	00:00 ~ 02:46	31-59.91 N	179-29.85 E	5,202		•	•	•	•	•	•	
St-402X	2013/11/11	05:40 ~ 05:47	31-30.25 N	179-29.98 E	5,300	•							
St-403-1	2013/11/11	08:50 ~ 09:25	31-00.63 N	179-37.73 E	5,303					•			
St-403-2	2013/11/11	11:05 ~ 13:02	31-00.04 N	179-29.96 E	5,356	•			•	•	•	•	Water sample
St-403-3	2013/11/11	18:00 ~ 19:00	31-00.04 N	179-30.03 E	5,355			•					
St-403X	2013/11/12	04:21 ~ 04:29	30-30.09 N	179-29.83 E	5,419	•							
St-404-1	2013/11/13	23:00 ~ 23:53	30-00.00 N	179-29.71 E	5,029					•		•	
St-404-2	2013/11/14	07:30 ~ 07:55	30-00.16 N	179-29.92 E	5,063				•		•		
St-404-3	2013/11/14	09:25 ~ 10:15	29-59.90 N	179-29.92 E	5,035	•							Water sample
St-404X	2013/11/14	13:11 ~ 13:17	29-30.08 N	179-29.94 E	4,724	•							
St-405X	2013/11/14	18:55 ~ 19:04	28-30.46 N	179-30.17 E	5,289	•							
St-406	2013/11/14	21:50 ~ 01:00	28-00.00 N	179-29.90 E	5,300		•	•	•	•	•	•	
St-405-1	2013/11/15	08:00 ~ 09:40	28-59.99 N	179-29.90 E	5,283		•		•	•	•	•	
St-405-MCD	2013/11/15	11:00 ~ 13:30	29-00.25 N	179-30.25 E	5,280								MOCNESS
St-405-2	2013/11/15	18:00 ~ 19:00	28-59.97 N	179-29.93 E	5,283			•					
St-405-MCN	2013/11/15	21:00 ~ 23:32	29-00.01 N	179-30.05 E	5,263								MOCNESS
St-501	2013/11/16	08:00 ~ 09:40	33-00.04 N	177-00.05 W	5,475		•		•	•	•	•	
St-501X	2013/11/16	12:47 ~ 12:53	32-30.03 N	177-01.34 W	5,061	•							
St-502	2013/11/16	16:18 ~ 19:04	31-59.97 N	176-59.99 W	5,331		•	•	•	•	•	•	
St-502X	2013/11/16	21:30 ~ 21:36	31-30.05 N	176-59.98 W	5,161	•							
St-503	2013/11/17	00:00 ~ 02:45	31-00.06 N	176-59.89 W	4,909		•	•	•	•	•	•	
St-503X	2013/11/17	05:40 ~ 05:47	30-30.40 N	177-00.01 W	5,232	•							
St-504	2013/11/17	08:54 ~ 10:28	30-00.04 N	176-59.97 W	5,340		•		•	•	•	•	
St-504X	2013/11/17	13:57 ~ 14:03	29-30.04 N	177-00.00 W	5,399	•							
St-505	2013/11/17	16:17 ~ 19:00	29-10.01 N	177-00.11 W	5,444		•		•	•	•	•	
St-504-2	2013/11/17	23:57 ~ 00:15	29-59.83 N	176-59.95 W	5,340							•	
St-503-2	2013/11/18	10:15 ~ 11:03	30-59.94 N	177-00.02 W	4,980		•				•		
St-503-MCD	2013/11/18	11:08 ~ 13:30	30-59.97 N	176-59.84 W	4,917								MOCNESS
St-503-MCN	2013/11/18	21:00 ~ 23:15	31-00.12 N	177-00.02 W	4,953								MOCNESS

Table 1-2. Outline of observation in KY1305 Leg 2.

Sta.	Ship time		Start Ob		Bottom depth (m)	Observation items							
	Date	Time	Lat	Long		XCTD	CTD (Water sample)	Jiggling squid	NORPAC net	Nackthai net	Fluoro Probe	2m ring net	other
St-601	2013/11/30	16:20	~	19:20	26-59.96 N	172-59.80 W	5,077	•	•	•	•	•	
St-601X	2013/11/30	21:48	~	21:54	27-30.00 N	172-59.71 W	5,059	•	•	•	•	•	
St-602	2013/11/30	23:30	~	02:35	27-50.98 N	172-59.91 W	5,079	•	•	•	•	•	
St-602X	2013/12/01	05:40	~	05:45	28-30.10 N	173-00.50 W	5,056	•	•	•	•	•	
St-603	2013/12/01	08:14	~	10:10	29-00.05 N	172-59.90 W	5,181	•	•	•	•	•	
St-603X	2013/12/01	13:10	~	13:18	29-29.83 N	172-58.25 W	5,182	•	•	•	•	•	
St-604	2013/12/01	16:20	~	19:15	30-00.02 N	173-00.05 W	5,377	•	•	•	•	•	
St-604-MCN	2013/12/01	21:00	~	23:25	30-00.25 N	172-59.64 W	5,379						MOCNESS
St-604-2	2013/12/02	00:00	~	01:10	30-00.01 N	172-55.31 W	5,377		•				
St-604-MCD	2013/12/02	10:56	~	13:25	30-00.38 N	173-00.37 W	5,381						MOCNESS
St-604X	2013/12/02	18:02	~	18:08	30-29.99 N	173-00.01 W	4,274	•					
St-605	2013/12/02	21:57	~	01:02	31-00.06 N	172-59.98 W	4,971	•	•	•	•	•	
St-605X	2013/12/03	04:35	~	04:41	31-29.93 N	172-58.90 W	5,401	•	•	•	•	•	
St-606	2013/12/03	08:13	~	10:00	31-59.91 N	172-59.76 W	5,574	•	•	•	•	•	
St-606X	2013/12/03	13:04	~	13:12	32-29.32 N	172-58.50 W	5,615	•	•	•	•	•	
St-606XX	2013/12/03	13:21	~	13:28	32-32.37 N	172-58.43 W	5,600	•	•	•	•	•	
St-607	2013/12/03	16:17	~	19:20	33-00.08 N	173-00.11 W	5,636	•	•	•	•	•	Argo float
St-701	2013/12/04	16:20	~	19:15	32-30.06 N	169-59.98 W	5,845	•	•	•	•	•	Argo float
St-701X	2013/12/04	21:22	~	21:27	32-00.00 N	169-59.91 W	5,736	•	•	•	•	•	
St-702	2013/12/04	23:30	~	02:30	31-30.17 N	170-00.25 W	5,779	•	•	•	•	•	
St-702X	2013/12/05	05:11	~	05:18	30-59.90 N	169-59.58 W	5,704	•	•	•	•	•	
St-703	2013/12/05	08:15	~	09:58	30-31.29 N	169-59.96 W	5,620	•	•	•	•	•	
St-703X	2013/12/05	12:52	~	12:58	30-00.03 N	170-00.05 W	5,457	•	•	•	•	•	
St-704	2013/12/05	16:17	~	19:03	29-30.00 N	170-00.01 W	5,183	•	•	•	•	•	
St-704X	2013/12/05	21:13	~	21:19	29-00.00 N	170-00.00 W	4,994	•	•	•	•	•	
St-705	2013/12/05	23:25	~	02:25	28-30.36 N	170-00.07 W	4,767	•	•	•	•	•	
St-705X	2013/12/06	05:07	~	05:13	28-00.03 N	170-01.29 W	4,663	•	•	•	•	•	
St-706	2013/12/06	08:14	~	09:50	27-30.92 N	170-00.07 W	4,541	•	•	•	•	•	
St-706X	2013/12/06	13:00	~	13:08	27-00.49 N	170-00.71 W	4,532	•	•	•	•	•	
St-707	2013/12/06	16:20	~	19:15	26-29.99 N	169-59.97 W	4,576	•	•	•	•	•	
St-801	2013/12/07	08:13	~	10:07	26-00.38 N	167-01.80 W	4,843	•	•	•	•	•	
St-801X	2013/12/07	13:06	~	13:15	26-29.50 N	167-00.51 W	4,354	•	•	•	•	•	
St-802	2013/12/07	16:18	~	19:08	27-00.09 N	167-00.15 W	4,174	•	•	•	•	•	
St-802X	2013/12/07	21:18	~	21:23	27-30.01 N	167-00.01 W	4,666	•	•	•	•	•	
St-803	2013/12/07	23:27	~	02:50	27-59.84 N	167-00.08 W	4,645	•	•	•	•	•	
St-803X	2013/12/08	05:36	~	05:42	28-30.12 N	166-57.52 W	5,060	•	•	•	•	•	
St-804	2013/12/08	16:20	~	19:05	28-59.94 N	166-59.79 W	5,161	•	•	•	•	•	
St-804X	2013/12/08	21:40	~	21:46	29-29.99 N	166-58.56 W	4,025	•	•	•	•	•	
St-805	2013/12/08	23:28	~	02:26	29-51.96 N	166-59.47 W	5,409	•	•	•	•	•	
St-805X	2013/12/09	05:35	~	05:53	30-30.03 N	167-00.00 W	4,864	•	•	•	•	•	
St-806	2013/12/09	08:14	~	09:55	30-59.97 N	167-00.03 W	5,709	•	•	•	•	•	
St-806X	2013/12/09	13:12	~	13:22	31-29.47 N	167-00.02 W	5,639	•	•	•	•	•	
St-807	2013/12/09	16:17	~	19:04	32-00.00 N	167-00.01 W	5,884	•	•	•	•	•	
St-901	2013/12/10	08:14	~	09:52	31-59.91 N	163-59.98 W	5,580	•	•	•	•	•	
St-901X	2013/12/10	12:58	~	13:08	31-30.48 N	164-00.36 W	5,609	•	•	•	•	•	
St-902	2013/12/10	16:18	~	19:00	31-00.08 N	163-59.92 W	5,590	•	•	•	•	•	
St-902X	2013/12/10	21:26	~	21:32	30-30.01 N	164-00.62 W	3,577	•	•	•	•	•	
St-903	2013/12/10	23:25	~	02:15	30-05.31 N	164-00.03 W	5,558	•	•	•	•	•	
St-903X	2013/12/11	05:22	~	05:28	29-29.90 N	164-00.82 W	5,739	•	•	•	•	•	
St-904	2013/12/11	08:10	~	10:09	29-00.05 N	164-00.01 W	5,318	•	•	•	•	•	
St-904X	2013/12/11	12:57	~	13:06	28-30.49 N	164-00.00 W	5,369	•	•	•	•	•	
St-905-1	2013/12/11	18:00	~	19:10	27-59.99 N	163-59.93 W	4,795	•	•	•	•	•	
St-905-2	2013/12/11	21:53	~	01:08	28-00.01 N	164-00.02 W	4,810	•	•	•	•	•	
St-905X	2013/12/12	04:29	~	04:37	27-30.01 N	163-58.61 W	5,216	•	•	•	•	•	
St-906	2013/12/12	08:15	~	09:53	26-59.90 N	163-59.72 W	5,094	•	•	•	•	•	
St-906X	2013/12/12	12:47	~	12:56	26-30.51 N	164-00.01 W	4,939	•	•	•	•	•	
St-907	2013/12/12	16:20	~	19:15	26-00.11 N	163-59.92 W	4,853	•	•	•	•	•	
St-907X	2013/12/12	21:15	~	21:21	25-30.01 N	164-00.28 W	4,777	•	•	•	•	•	
St-908	2013/12/12	23:26	~	02:30	25-00.24 N	164-00.25 W	4,937	•	•	•	•	•	
St-1001	2013/12/13	23:25	~	02:28	26-30.02 N	161-00.16 W	5,011	•	•	•	•	•	
St-1001X	2013/12/14	05:20	~	05:25	26-59.91 N	160-59.51 W	3,611	•	•	•	•	•	
St-1002	2013/12/14	08:11	~	09:50	27-29.96 N	160-59.82 W	5,042	•	•	•	•	•	
St-1002X	2013/12/14	12:53	~	13:05	27-59.56 N	160-59.13 W	4,035	•	•	•	•	•	
St-1003	2013/12/14	16:15	~	19:11	28-29.84 N	160-59.92 W	5,302	•	•	•	•	•	
St-1003X	2013/12/14	21:08	~	21:18	28-59.98 N	160-58.96 W	5,869	•	•	•	•	•	
St-1004	2013/12/14	23:29	~	02:30	29-29.89 N	161-00.18 W	5,462	•	•	•	•	•	
St-1004X	2013/12/15	05:18	~	05:30	29-59.88 N	161-00.00 W	5,402	•	•	•	•	•	
St-1005	2013/12/15	08:12	~	09:49	30-29.55 N	161-00.00 W	5,894	•	•	•	•	•	
St-1005X	2013/12/15	12:50	~	13:05	30-59.81 N	160-59.97 W	5,697	•	•	•	•	•	
St-1006	2013/12/15	16:19	~	19:00	31-29.88 N	161-00.02 W	5,616	•	•	•	•	•	
St-1101	2013/12/16	16:15	~	19:00	31-00.02 N	158-00.15 W	5,820	•	•	•	•	•	
St-1101X	2013/12/16	21:06	~	21:16	30-30.01 N	157-59.33 W	5,821	•	•	•	•	•	
St-1102	2013/12/16	23:24	~	02:20	29-59.99 N	158-00.03 W	5,829	•	•	•	•	•	
St-1102X	2013/12/17	05:11	~	05:21	29-30.05 N	158-00.00 W	5,786	•	•	•	•	•	
St-1103	2013/12/17	08:12	~	09:50	28-59.98 N	157-59.99 W	5,438	•	•	•	•	•	
St-1103X	2013/12/17	12:54	~	13:07	28-30.18 N	157-59.43 W	5,634	•	•	•	•	•	
St-1104	2013/12/17	16:16	~	19:00	27-59.89 N	157-59.99 W	5,605	•	•	•	•	•	
St-1104-MCN	2013/12/17	20:26	~	23:15	27-59.99 N	158-00.12 W	5,609						MOCNESS Bongo net
St-1104-2	2013/12/18	00:00	~	01:03	28-01.04 N	157-56.98 W	5,538		•				
St-1104-MCD	2013/12/18	08:10	~	12:05	27-59.95 N	157-59.99 W	5,605					•	MOCNESS Bongo net
St-1104X	2013/12/18	14:18	~	14:30	27-30.18 N	157-57.51 W	5,459	•	•	•	•	•	
St-1105	2013/12/18	16:20	~	19:03	27-03.94 N	157-59.43 W	5,381	•	•	•	•	•	
St-1105X	2013/12/18	21:26	~	21:36	26-29.99 N	158-00.86 W	5,155	•	•	•	•	•	
St-1106	2013/12/18	23:19	~	02:22	26-02.20 N	158-00.21 W	3,754	•	•	•	•	•	
St-1106X	2013/12/19	05:06	~	05:16	25-29.99 N	157-59.99 W	4,974	•	•	•	•	•	
St-1107	2013/12/19	08:08	~	09:54	24-59.95 N	158-00.05 W	4,523	•	•	•	•	•	
St-1107X	2013/12/19	13:00	~	13:12	24-30.19 N	158-01.22 W	4,599	•	•	•	•	•	
St-1108	2013/12/19	16:15	~	19:10	24-00.01 N	157-59.97 W	4,449	•	•	•	•	•	
St-1201	2013/12/20	14:59	~	19:00	24-00.00 N	155-00.04 W	3,787	•	•	•	•	•	
St-1201X	2013/12/20	21:19	~	21:29	24-30.00 N	155-01.07 W	4,677	•	•	•	•	•	
St-1202	2013/12/20	23:31	~	02:25	24-59.40 N	154-59.91 W	4,741	•	•	•	•	•	
St-1202X	2013/12/21	05:17	~	05:27	25-29.94 N	154-59.96 W	5,067	•	•	•	•	•	
St-1203	2013/12/21	08:13	~	09:55	25-59								

6.2 Distribution and abundance of paralarvae of neon flying squid (*Ommastrephes bartramii*)

A total of 91 neon flying squid paralarvae (confirmed by DNA analysis as *Ommastrephes bartramii*) (Fig. 2) were collected by using a 2-m ring net from surface waters. The paralarvae were occurred in the sea surface temperature (SST) range of 19.3-24.5°C. Very few paralarvae were found on the longitudinal sampling lines 157°E and 167°E, and almost all paralarvae were collected from 176°E and westward (Fig. 3).



Fig. 2 A paralarvae (2.72 mm in mantle length) of neon flying squid (*Ommastrephes bartramii*) collected by using a 2-m ring net during the KY0305 research cruise.

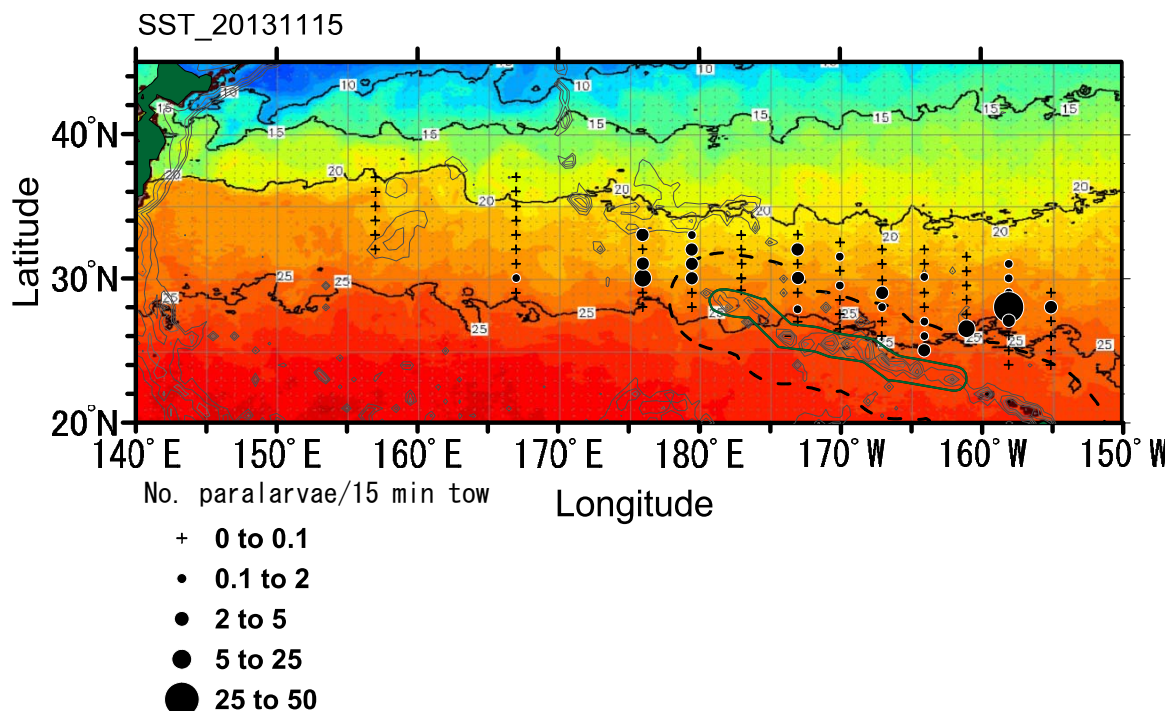


Fig. 3 Distribution and abundance of paralarvae of neon flying squid (*Ommastrephes bartramii*) collected by using a 2-m ring net towing in surface water during KY0305 research cruise from October to December 2013.

6.3 Distribution and abundance of adult neon flying squid (*Ommastrephes bartramii*)

A total of 76 adult neon flying squid (10 copulated mature female, 12 immature female, 54 mature male) were collected by hand jigging (Fig. 4).

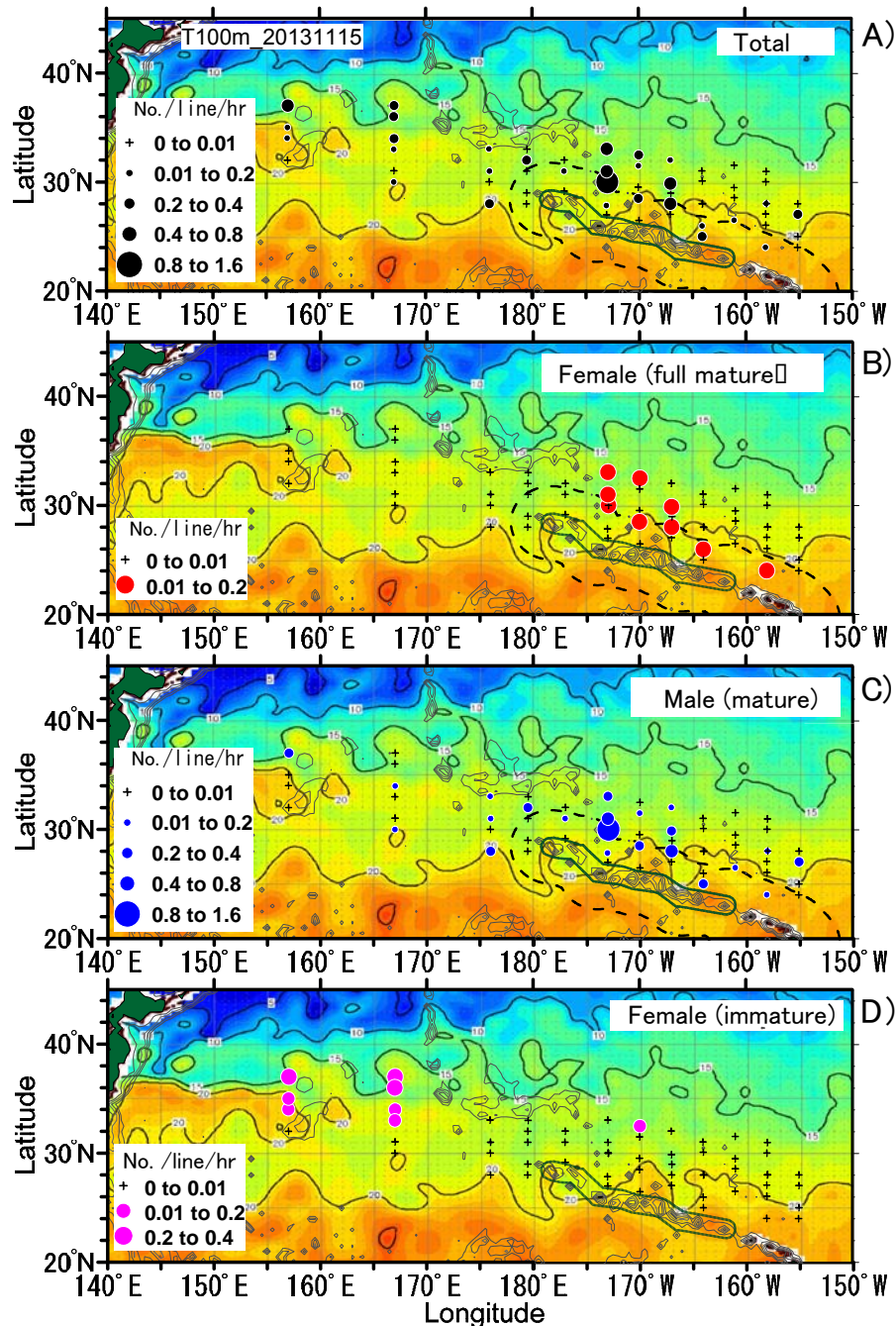


Fig. 4 Distribution and abundance of adult neon flying squid (*Ommastrephes bartramii*) collected by hand jigging during KY0305 research cruise from October to December 2013, with contour map of water temperature in the 100 m depth layer. A) Total female and male squid, B) Copulated full mature female, C) Mature male, D) Immature female.

6.4 Oceanographic observations conducted by CTD and XCTD

During the cruise, 500m depth hydrographic observations were conducted for each longitudinal survey line (Fig 5-1 ~ Fig. 5-5).

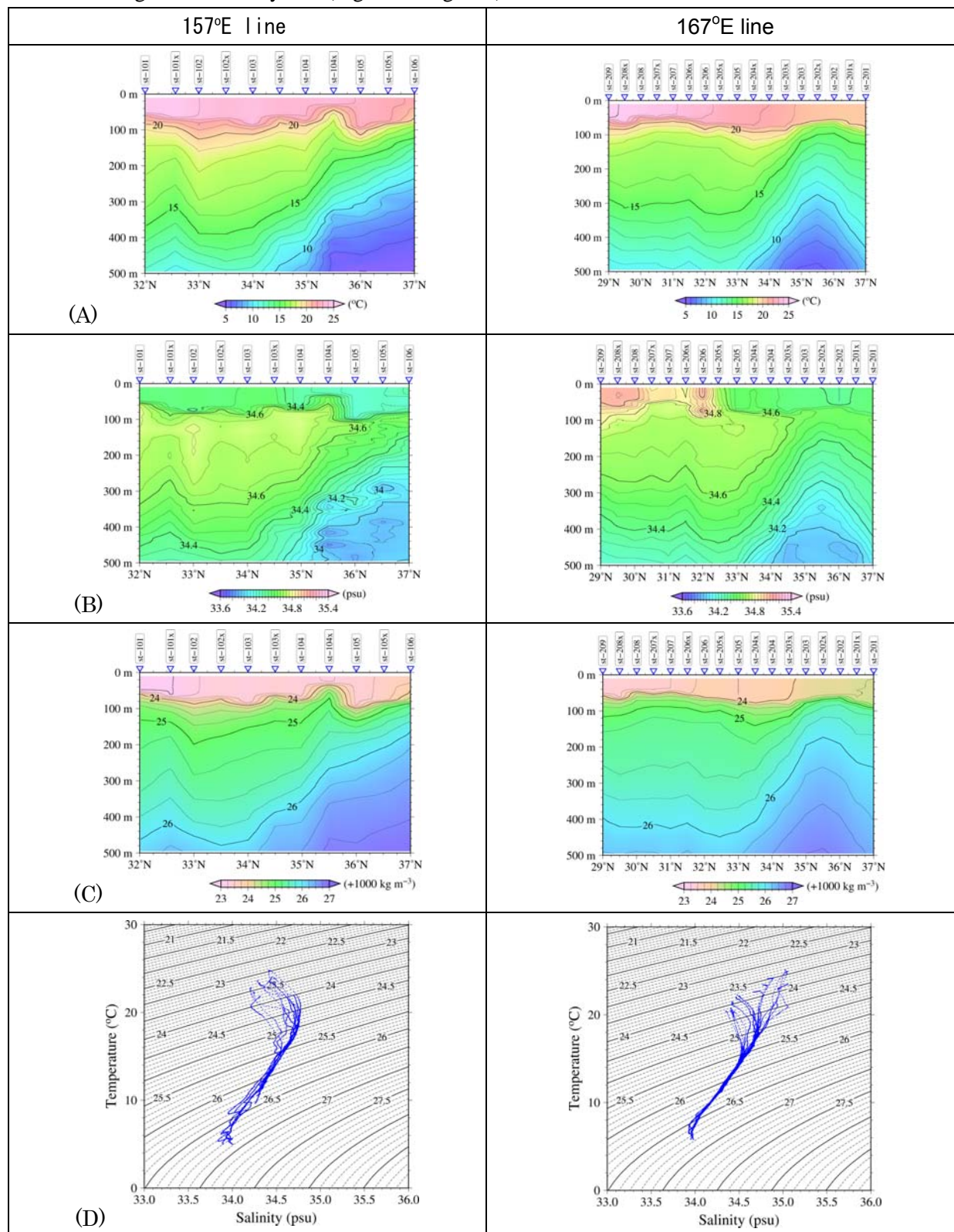


Fig. 5-1 Water temperature °C(A), salinity (B), density (C) and T-S diagram (D) from surface to 500 m depth on the latitudinal section of each longitude line (157°E and 167°E).

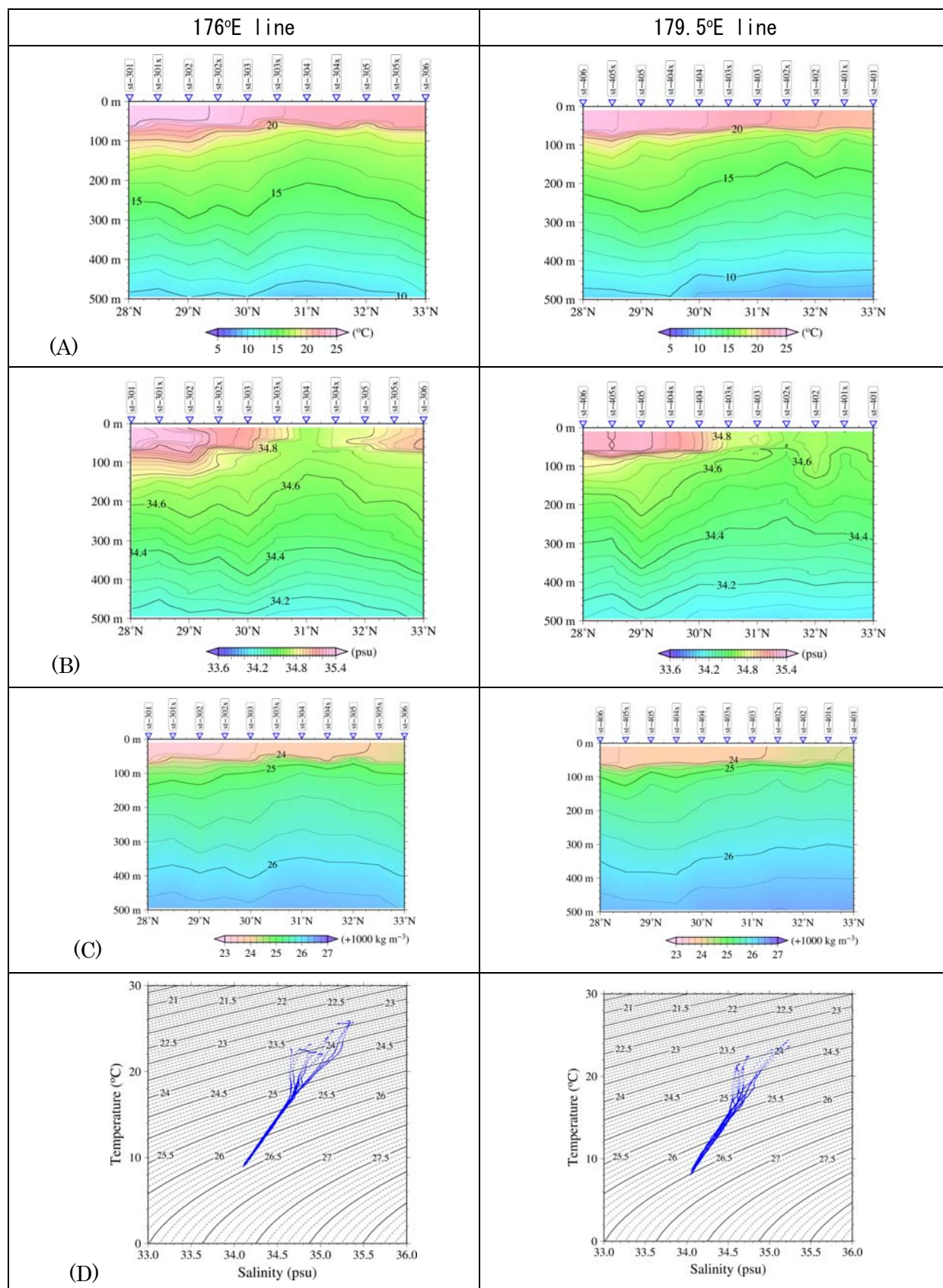


Fig. 5-2 Water temperature °C(A), salinity (B), density (C) and T-S diagram (D) from surface to 500 m depth on the latitudinal section of each longitude line (176°E and 179.5°E).

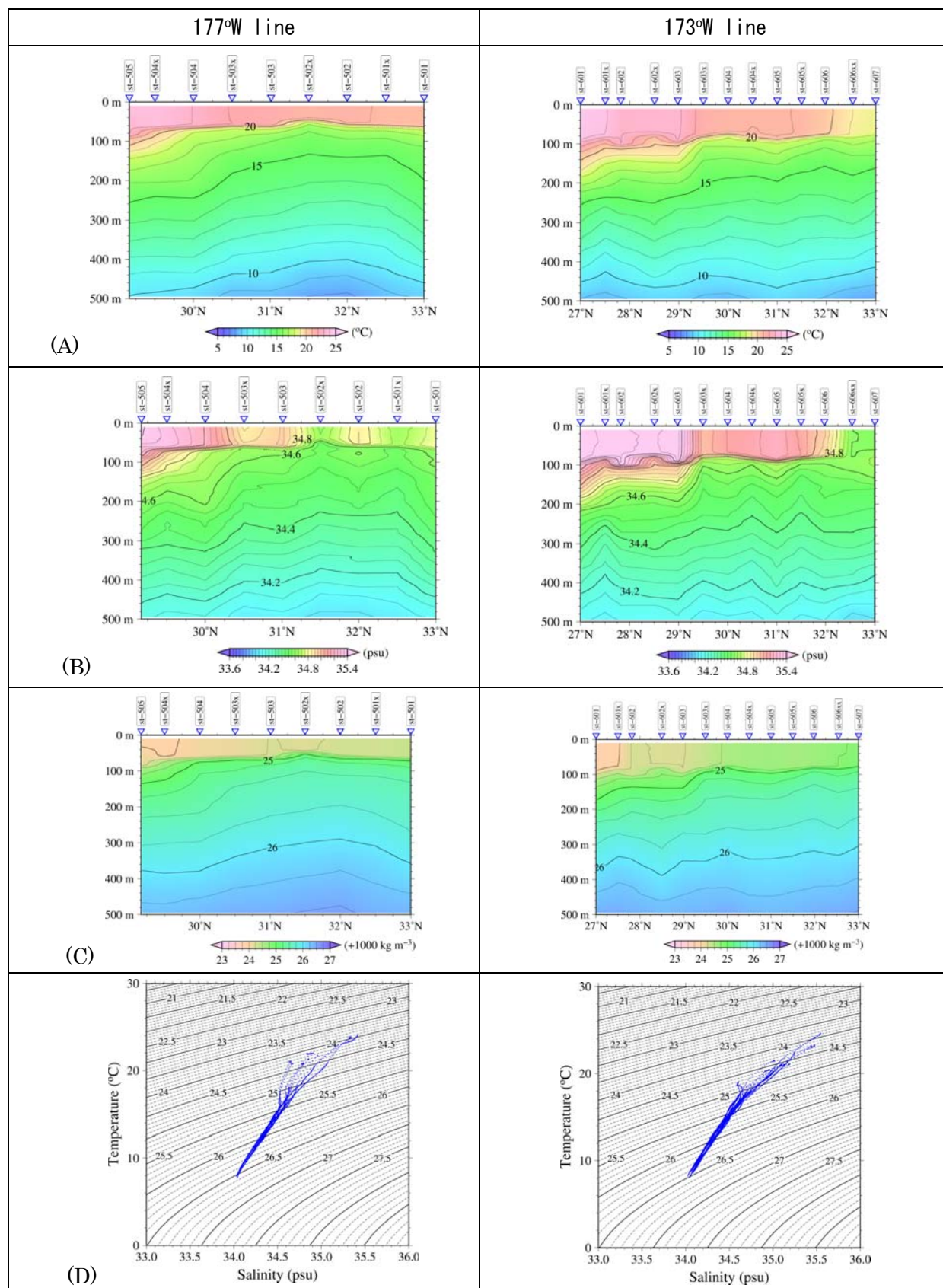


Fig. 5-3 Water temperature °C(A), salinity (B), density (C) and T-S diagram (D) from surface to 500 m depth on the latitudinal section of each longitude line (177°W and 173°W).

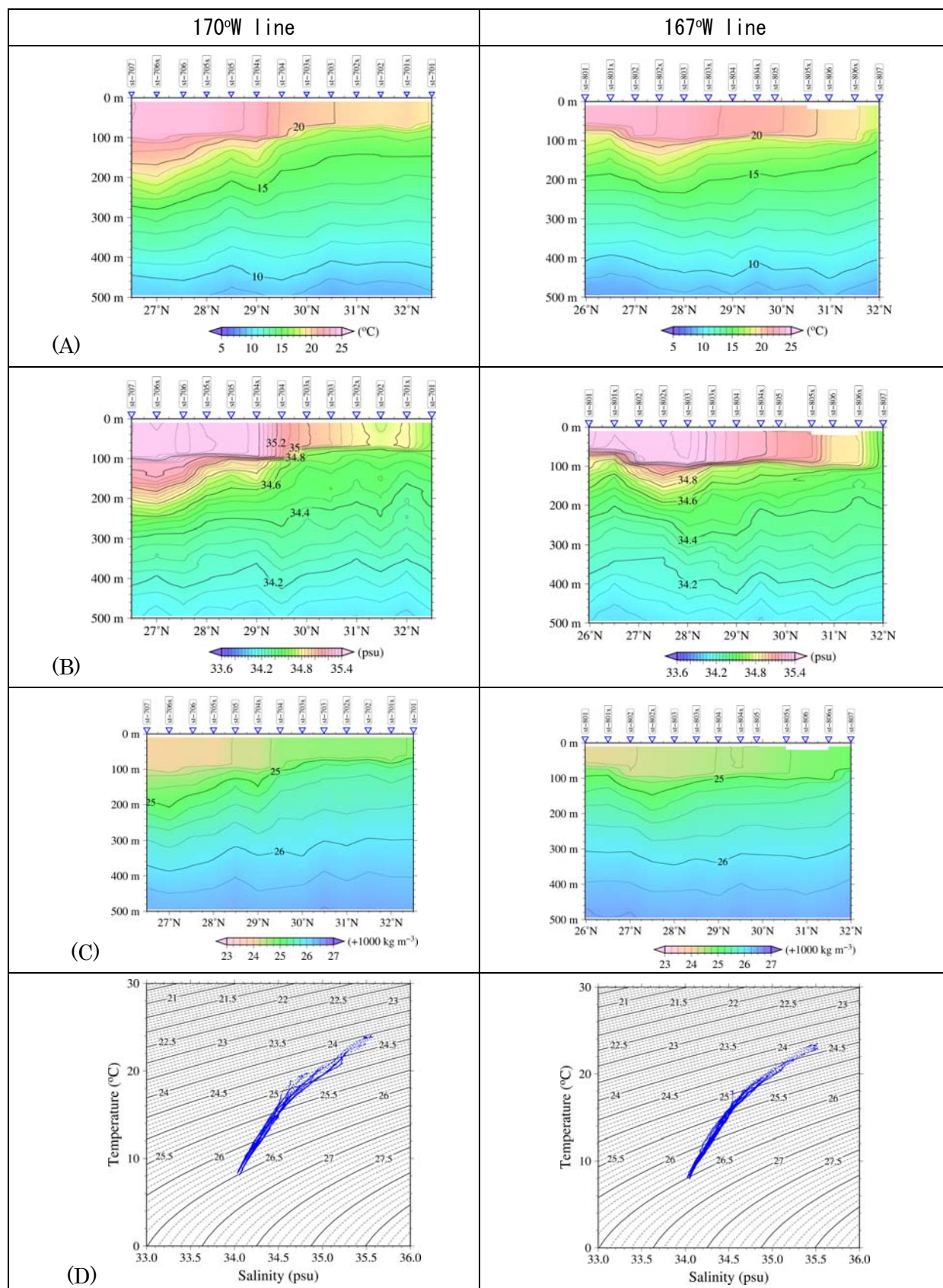


Fig. 5-4 Water temperature °C(A), salinity (B), density (C) and T-S diagram (D) from surface to 500 m depth on the latitudinal section of each longitude line (170°W and 167°W).

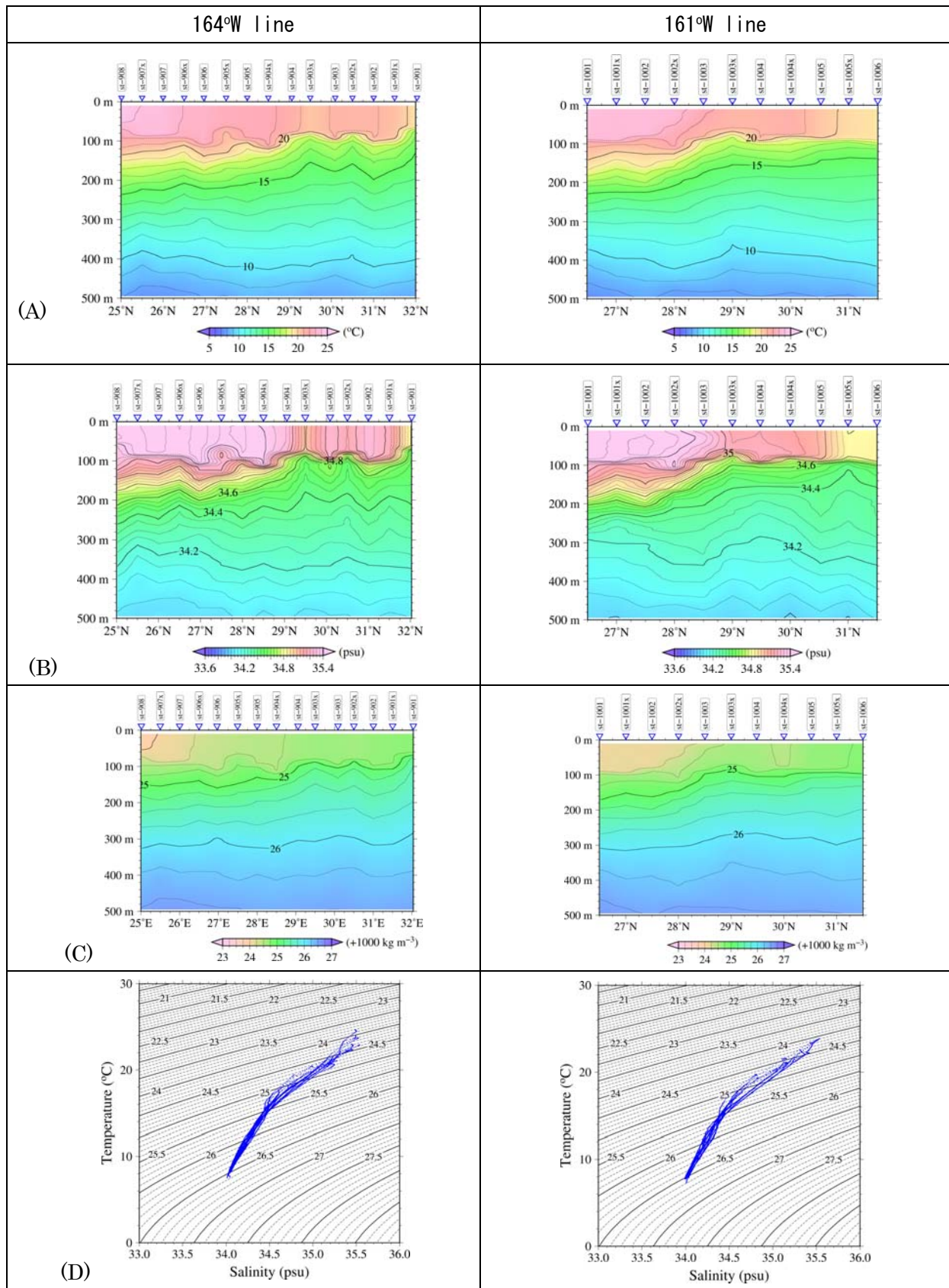


Fig. 5-5 Water temperature °C (A), salinity (B), density (C) and T-S diagram (D) from surface to 500 m depth on the latitudinal section of each longitude line (164°W and 161°W).

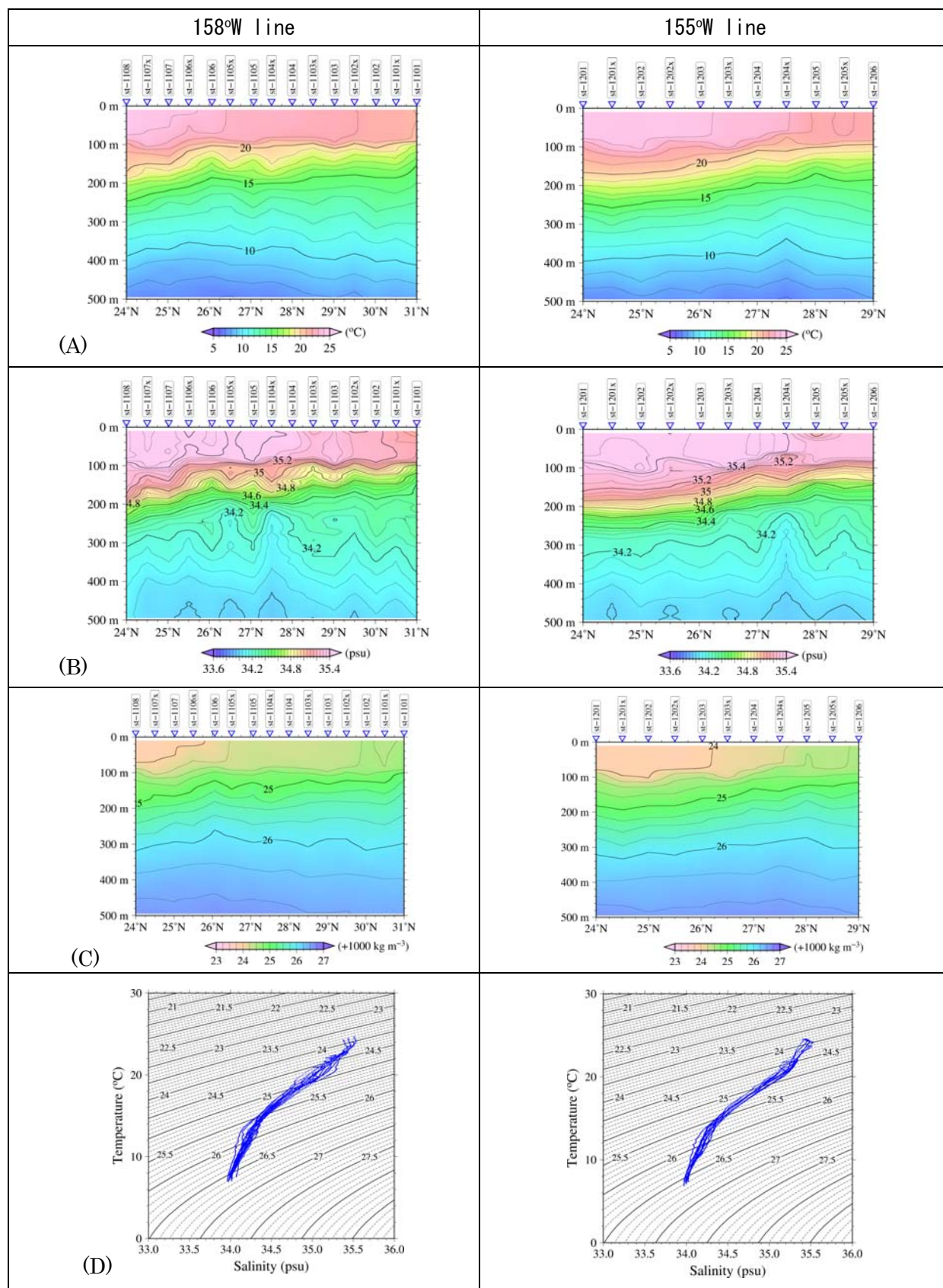


Fig. 5-6 Water temperature °C(A), salinity (B), density (C) and T-S diagram (D) from surface to 500 m depth on the latitudinal section of each longitude line (158°W and 155°W).

6.5 Artificial fertilization experiments

Artificial fertilization experiments were done on *Ommastrephes bartramii*, *Sthenoteuthis oualaniensis* and *Eucleoteuthis luminosa*. Embryonic development and survival rate were observed at different temperatures. Swimming behavior of *O. bartramii* paralarvae was also observed.

For *O. bartramii*, the percentage of fertilization in the artificial fertilization experiments ranged from 16% (at 16°C) to 98% (at 22°C), and development was highly temperature dependent. Normal development with high (>50%) survival rates was observed between 18 and 25°C (Fig. 6).

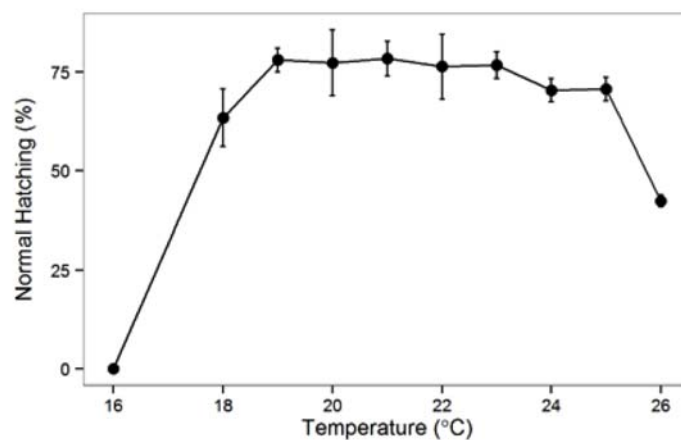


Fig.6 Percentage of normal hatching (bars indicate 95% confidence interval) in *Ommastrephes bartramii* plotted against incubation temperatures at stage 26.

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