Nécrologie : Monsieur le Professeur Yutaka UNO, l'ancien Président de la Société

追悼：宇野 寛先生

本学会元会長で，名誉会員の宇野寛先生（東京水産大学名誉教授）は 2009 年 12 月 31 日に 85 歳（1924－2009）でご逝去されました。深く哀悼の意を表します。

宇野 寛先生 略歴

1944：農林省水産講習所本科養殖科卒業
1951：京都大学農学部水産学科卒業
1951：東京水産大学小湊実験場助手
1956：東京水産大学小湊実験場講師
1965：東京水産大学教授
在任中，付属実験実習場長・付属図書館長の要職を歴任
1985：日仏海洋学会会長（1989/3 まで）
1990：海中開発技術協会副会長（1992/3 まで）

1966：日仏海洋学会賞受賞
1978：パルムアカデミー章（フランス）受章
1981：カヴァリエール章　（イタリヤ）受章

宇野寛先生は教授にご就任以来，大学での研究活動以外に海外との情報交換にも積極的に取り組まれて来られました。イギリス，アイルランド，フランス，スペイン，イタリヤ，ギリシャ等の西欧諸国を筆頭に東欧，アジア，アフリカ諸国にもその対象を広げられました。先生は持ち前の行動力と前向きの姿勢で頻繁にこれら諸国に出向かれ，多くの海外研究者と交流を深めるとともに，研究者や留学生招聘を積極的に推進されました。また，日本からの研究者や留学生派遣にも力を注がれました。

教育においても，日本各地や海外の新しい情報を取り入れた先生の新鮮な講義は学生にとって大変魅力的であり，教室はつねに満杯の状態でした。

海洋科学分野において日本と関係の深いフランスとの研究交換には特に熱心で，大学・学会・日仏会館を通じて多くの訪問研究員や留学生を日本に招聘されると共に日本側でも若手研究者にフランス政府の給費留学を奨励されました。これは学会初代会長の故・佐々木忠義先生との深いご親交で培われたものと推察されます。宇野先生のご努力で相互交換が実現した両国の留学生は十指を越える数に上ったと記憶しています。特にご専門の水産増養殖学分野では，将来の指導者となる多くの人材を育てられ，ホタテ貝・カキ・日本産アサリ・アワビ・クルマエビ・サケ・スズキ・マダイなどフランスの有用魚介類の増養殖技術の向上に大きく貢献されています。これらの功績が高く評価され，1978 年にフランス政府から教育功労勲章シュヴァリエ章 l'Ordre des Palmes Academiques au grande de Chevalier を贈与

されたことは会員一同の喜びであると共に，後輩研究者の大きな励みになりました。

また，学会事業の一環としてモンペリエ・マルセイユ・仙台・清水などで行われた日仏海洋学シンポジウムにおいて，大会委員長ほか重要なポストを務めて大会を成功に導く成果を上げ，両国の学会発展にも大きく貢献されています。

かつて研究室でお世話になっていた私は，1970年に先生がフランスから初めて招聘された国立海洋開発研究所（CNEXO，現在のIFREMER）の二人の若手研究員を紹介され，日本での世話を依頼されました。彼らは研究室をベースに，日本各地の研究機関を訪問し，各所で増養殖・資源管理技術などを研修しました。彼らから聞いた研修旅行の印象は，学んだ成果もさることながら，引率された宇野先生の，成果をその場で瞬時に分析しフランスに応用する糸口を見いだす高い洞察力とのことでした。彼らは1年後に帰国し，所属研究所から立派な報告書を届けてきました。

その2年後，今度は私が先生から勧められ，フランス政府給費留学生をベースに，彼らの活躍するIFREMERにおいて研究生活を送る機会をいただきました。その折り，研究所において親身になって受け入れてくれた生物学研究グループの責任者は，彼らの上司であった故・Lucian LAUBIER博士でした。後年になって知ったことですが，LAUBIER博士は日本にバチスカーフが回航されたときのクルーとして来日され，すでに佐々木先生や宇野先生と親交を持たれていたそうです。

今，こうした研究者間の深い親交の絆が日仏交流の底に脈々と流れていることが強く感じられます。その一翼を担われた宇野先生のご薫陶が今後も引き継がれ，日仏両国の絆がさらに発展するよう願いながら，会員の皆様と共に先生のご冥福を心よりお祈り致します。

小池康之，日仏海洋学会幹事

Commémoration : Monsieur le Professeur Yutaka Uno,

Up to you !

1970年，私は日本政府給費留学生として宇野先生の研究室で指導を受ける機会に恵まれた。当初，言葉の問題で意思疎通に戸惑ったが，先生は忍耐強く理解できるまで説明して下さった。研究室において，学生の研修目的や利点について先生自ら簡潔明瞭に説明して下さったが，このような教育はフランスやヨーロッパではとても望めないことである。また，フィールドにおける水産増養殖に関する先生の知見は大変広範囲で，ウナギ，ニジマス，ホタガイ，アワビ，クルマエビ，マダイ，スズキなどの魚介類から種苗放流，人工魚礁などに及び，その問題点や改良点を明らかにされた。私やその跡に続いた留学生達は，先生の広い交友関係のお陰で，これらのフィールドへの研修や視察で受け入れられ，多くの成果を上げることができた。こうして私たちが持ち帰った研修報告は，フランスの科学者に高く評価されたに違いない。

先生はいつも変わらぬ情熱と親密さをもって私たちに対応して下さり，共に意見を交わした仕事の跡では，食事や酒宴を共にして息抜きの機会も与えて下さった。そして最後はいつも相手に手をさしのべながらの一言，「Up tou you !」で結ばれた。

Joël QUERELLOU：ジョエル　ケレルー
Director, Microbiology of Extreme Environment, 極限環境微生物部部長
IFREMER（Institut français de recherche pour l'exploitation de la mer）：
フランス海洋開発研究所

Good, good, good !

私は東京水産大学にポスドクで受け入れていただく機会を得ましたが，多くのフランス人留学生と同様，宇野先生の助言と指導を受ける恩恵を得ることができました。期間中，宇野先生の研究職としての真剣さ，博識および影響力に強い印象を受けました。

ここで，先生から学んだ目には見えない教訓を紹介します。

その一つは，フィールドでの情報収集法についてです。先生の引率で数名の研修生と共に種苗生産施設を見学した際，先生は帰りの列車の中で一人で席に着くと，休むいとまもなくその日収集した資料を技術的にまた経済的に分析し，熱心にノートにまとめ始めました。それは，自分の仕事に没頭する一人の教授として，また，研究者としての姿でありました。取得した情報を即座に処理するという印象的な姿勢は教科書からは得られない現実的な教えであり，その後，自分自身の研究生活に大いに役立てることができました。

二つ目はもう少し軽いものです。1985 年の秋，フランス視察団の旅行計画をお願いした時ですが，彼らの訪問先に対する要求があまりにも多すぎるので，私はためらいながら先生に相談しました。先生は要求内容に次々と目を通すと，驚いたことに，「Good, good, good !」を連発して受け入れてくれたのです。苦労して旅行計画を立てた跡，先生はおいしいワインと夕食をごちそうして下さいました。帰途の私の足は思わずスキップを踏むほど浮き立っておりました。

Catherine MARIOJOULS, Professeur：カトリーヌ　マリオジュウルス（教授）
Département Science de la Vie et Santé：生命・健康科学部
Institut des Science et Industries du Vivant et de l’Environnement：
生物環境科学工学研究所

Bon d’ccord !

日本政府給費留学生として東京水産大学でお世話になっていた頃，宇野先生と廊下で何度かお会いする機会があったが，そのたびに他の先生方とは違った活発で心のこもった挨拶と態度に心を惹かれていた。

数年後，訪問研究員として再び来日し，今度は宇野先生の研究室にお世話になる機会を得た。フランス好みでありながらフランス語を話せない先生との会話はもっぱら英語で行ったが，友好的な研究室では他の留学生共々私たちは驚くほど早く日本語を覚えることができた。

私のフィールドでの研究計画を相談した際，湯飲み茶碗でウイスキーを酌み交わしながらの話し合いは，常に先生のお気に入りの力強い一言，「Bon d’accord !」（よし，分かった !）で了解してもらえた。このフランス語の一言には，水産学の日仏交流に対する先生の強い好奇心と熱意が常に込められていた。

François SIMARD，フランソワシマール
Conseiller pour la pêche et les Affaires maritimes，漁業及び海事顧問
Centre de Coopération pour la Méditeranée，地中海協力センター
Union internationale pour la conservation de la nature，国際自然保護連合

訃報　森田良美名誉会員

森田良美名誉会員（東京水産大学名誉教授）は，2009 年 9 月 24 日逝去されました。森田先生は、1922 年 8 月 12 日東京都のお生れで、1944 年 9 月に東京帝国大学理学部化学科を卒業された後、名古屋大学助手を経て、1954 年 5 月から東京水産大学に講師として勤務されました。その後、1957 年 4 月からは助教授、1971 年 7 月からは教授として、1986 年 3 月に停年退官されるまで、東京水産大学において教育研究にご活躍されました。特に 1973 年 4 月に新たに発足した海洋環境工学科の所属となられ、東京水産大学における環境化学の教育研究の基礎を築かれました。研究面では、水圏環境の微量重金属元素の分析と動態に関して先駆的なお仕事をされ、国内外から高い評価を受けられました。この間、十和田湖における重金属汚染の実態を初めて明らかにして対策への道を切り開かれるなど、社会的にも大きく貢献されました。また、第 1 回南極観測において宗谷に随伴した海鷹丸に乗船して南極洋の調査をされたのを初め、多数の乗船観測を通じて海洋の化学的研究においても顕著な業績を上げられました。

日仏海洋学会には 1963 年 4 月に入会され、学会にも多大なご貢献をいただきました。多くの役職、委員を歴任されましたが、1984 年 4 月から 1986 年 3 月までは副会長として学会の運営にあたっていただきました。その後も名誉会員として引き続き後進へのご助言をいただいていたところです。学会として先生のご貢献に改めて感謝申し上げ、謹んでご冥福をお祈りするものであります。

神田穣太（東京海洋大学）

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Société franco-japonaise d'océanographie, Tokyo

Distribution and population structure of salps off Adelie Land in the Southern Ocean during austral summer, 2003 and 2005

Atsushi ONO, Takashi ISHIMARU and Yuji TANAKA

Abstract: To investigate the distribution and population structure of salps which sustain the Antartcic ecosystems, stratified and quantitative samplings using a plankton net with mouth area of 8 m^2 (RMT 8) were conducted off Adelie Land during austral summer of 2003 and 2005. Observed were two salp species: *Salpa thompsoni* and *Ihlea racovitzai*, the former being dominant numerically. Mature aggregates and immature solitaries mainly occurred in the deep layer while immature aggregates and mature solitaries were observed in the surface layer. This result implies that *S. thompsoni* are ontogenetic vertical migrators. No mature individuals of aggregates and/or solitaries of *S. thompsoni* occurred in the south of 65°20′S. This observation suggests that the *S. thompsoni* population distributed at high latitude (south of 65°20′S) was not reproducing.

Keywords: *Salpa thompsoni, distribution, population structure, Southern Ocean*

1. Introduction

Salpa thompsoni is the most abundant salp species and major herbivorous zooplankton together with krills and copepods in the Southern Ocean (VORONINA, 1998). *S. thompsoni* is known to be distributed at middle latitude (45–55°S) of the Southern Ocean (FOXTON, 1966). Recent reports have suggested that the distribution of *S. thompsoni* has been shifting southward (PAKHOMOV *et al.*, 2002; ATKINSON *et al.*, 2004). *S. thompsoni* has high reproductive (DAPONTE *et al.*, 2001) and ingestion abilities (HUNTLEY *et al.*, 1989; DUBISCHAR and BATHMANN, 1997; PERISSINOTTO and PAKHOMOV, 1998). This species occasionally forms a dense swarm and dominates macrozooplankton communities (e. g., HOSIE, 1994; NISHIKAWA *et al.*, 1995; DUBISCHAR and BATHMANN, 1997; CHIBA *et al.*, 1998; HOSIE *et al.,* 2000). Possible negative effects of the salp swarm on reproduction and survival of larvae of *Euphausia superba* have been emphasized (HUNTLEY *et al.*, 1989; LOEB *et al.*, 1997), thus altering the Southern Ocean food web (ATKINSON *et al.*, 2004); however, *S. thompsoni* life cycle strategies in the Southern Ocean still remain unknown.

Like the other Thaliacea, salps have a unique reproductive strategy, that is, a generation change happens between sexually reproducing aggregates and asexually reproducing solitaries (GODEAUX *et al.*, 1998). Therefore, reproductive states of both aggregates and solitaries need to be studied to understand salps' generation mechanism (CHIBA *et al.*, 1999). CALDWELL (1966) and FOXTON (1966) reported *S. thompsoni* also distributed in the depths deeper than 200 m. FOXTON (1966) found solitaries occurred in the deeper layers and explained individuals occurring in the deeper layers may be of importance in the life cycle of *S. thomsponi* and in the maintenance of the shallower population. Furthermore, previous studies

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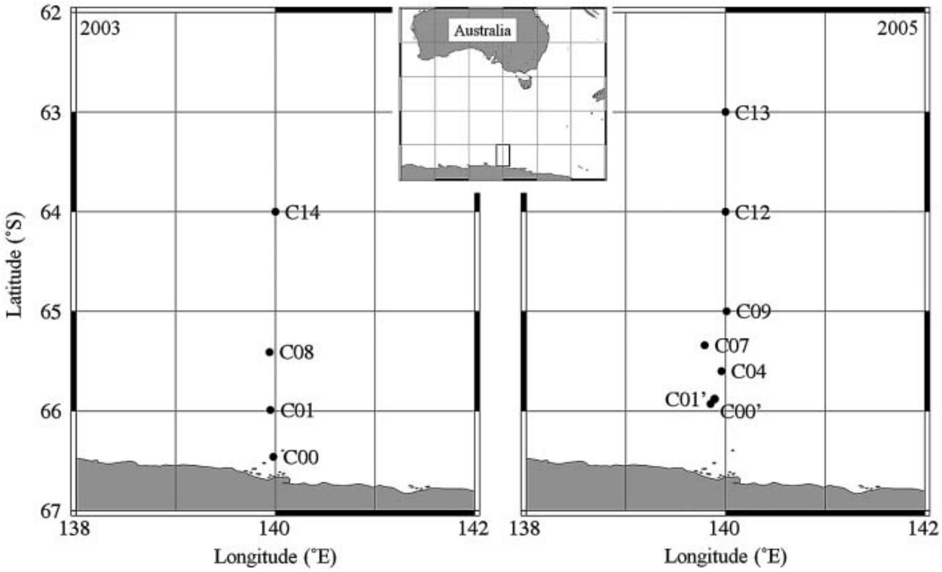

Fig. 1. Sampling and observation stations off Adelie Land in 2003 and 2005.

(FOXTON, 1966; CASARETO and NEMOTO, 1986) have reported the different vertical distribution of the maturity stage's composition of *S. thompsoni*. It is thus necessary to clarify the vertical distribution and population structure in the mesopelagic zone to understand the life cycle strategies of *S. thompsoni*; however, there is little information on the life cycle strategies below 200 m.

Therefore, we conducted stratified and quantitative samplings to understand the distribution and population structure of salps off Adelie Land in the Southern Ocean during austral summer of 2003 and 2005.

2. Materials and methods

Samplings were conducted by TR/V Umitaka-Maru (1886 ton) of Tokyo University of Marine Science and Technology from 4 to 7 February in 2003 and from 12 to 15 February in 2005 along 140°E off Adelie Land in the Southern Ocean (Fig. 1). Samples were collected using an RMT 8 (Rectangular Midwater Trawl, mouth area: 8 m^2, mesh opening: 4.5 mm, Ocean Scientific International Ltd., Baker *et al.*, 1973), which was obliquely towed in 3–6 different strata between the surface and 2886 m (Table 1). In 2003, maximum sampling depths at Stns. C14 and C08 were 2886 and 2300 m, respectively. At Stns. C01 and C00, deepest depths sampled were 180 and 835 m, respectively. In 2005, samplings were basically conducted in 6 strata between the surface and 2000 m (0–50–100–200 m and 200–500–1000–2000 m). At Stns. C04, C01' and C00' where bottom depths are shallower than 1000 m, maximum sampling depths were 950, 200 and 194 m, respectively. The ship's speed during the net tows was 1 m s^{-1}. Samples were immediately preserved onboard in buffered 5% formalin-seawater solution. The filtered volume was calculated from the mouth area of the net and flow meter counts. Samples collected from 200–500 m at Stn. C07 and 100–194 m at Stn. C00' in 2005 were excluded from the analysis because of defective preservations.

In the laboratory, subsamples were taken and divided into 1/2 to 1/8 using a MOTODA plankton splitter (MOTODA, 1959) when the initial catch was large. The zooplankton were divided into the eleven taxa (Salpida, Siphonophora, Medusae, Chaetognatha, Polychaeta, Ostracoda, Copepoda, Amphipoda, Euphausiacea, Decapoda and Pteropoda), and wet weight to the nearest 0.01 g were determined for each taxon using an electrobalance. The conversion factors from wet weight to carbon weight was from CAUFFOPÉ and HEYMANS

Table 1. List of sampling data during TR/V Umitaka-maru cruises in 2003 and 2005.

Station	Location		Date	Local time	Sampling layer (m)
	(S)	(E)			
C00	66° 25.6′	139° 47.0′	2003/2/4	05:02–06:42	0–200–500–835
C01	65° 55.8′	139° 55.7′	2003/2/4	14:55–15:28	0–50–100–180
C08	65° 25.3′	140° 02.2′	2003/2/5	13:41–15:34	0–500–1000–2300
C14	63° 54.6′	139° 52.0′	2003/2/7	13:19–15:13	500–1000–2000–2886
	63° 48.0′	139° 50.4′	2003/2/7	16:49–17:32	0–77–193–474
C00’	65° 54.3′	139° 57.1′	2005/2/12	05:37–07:37	0–50–100–194
C01’	65° 51.5′	139° 59.0′	2005/2/12	00:36–02:11	0–50–100–200
C04	65° 35.2′	139° 55.6′	2005/2/12	19:55–22:13	200–500–800–950
	65° 31.9′	139° 46.8′	2005/2/12	22:42–00:20	0–50–100–200
C07	65° 20.2′	139° 45.7′	2005/2/13	09:25–12:24	200–500–1000–2000
	65° 24.7′	139° 35.1′	2005/2/13	12:47–14:27	0–50–100–200
C09	65° 03.1′	139° 58.5′	2005/2/13	23:21–02:26	200–500–1000–2000
	65° 05.0′	139° 53.9′	2005/2/14	02:52–03:30	0–50–100–200
C12	64° 03.4′	139° 58.6′	2005/2/14	16:56–20:03	200–500–1000–2000
	64° 06.0′	139° 57.8′	2005/2/14	20:16–22:12	0–50–100–200
C13	62° 56.7′	140° 03.9′	2005/2/15	05:05–08:19	200–500–1000–2000
	62° 54.5′	140° 07.8′	2005/2/15	08:35–10:16	0–50–100–200

Table 2. Description of each maturity stage of *Salpa thompsoni* aggregate.

Maturity stages	Embryonic state	Placenta	Muscle bands	Eleoblast	Remark
0	unfertilized	×	×	×	
1	fertilized	×	×	×	
2	developing	○	×	×	
3	developing	○	○	○	Small eleoblast
4	fully developed	○	○	○	Eleoblast as large as placenta and clear muscle bands
spent	released	–	–	–	Only placental scar
X	empty or no embryo	–	–	–	

Table 3. Description of each maturity stage of *Salpa thompsoni* solitary.

Maturity stages	Stolon state	Remark
1	unsegmented	With short stolon
2	developing	With segmented stolon and longer than stage 1
3	developing	The first stolon block not differentiated
4a		The first stolon block differentiated
4b	mature	Presence of well-developed the second block
5a		The first block released and presence of the test scar

(2005) for Siphonophora and Davis and Wiebe (1985) for other taxa except for Salpida. Species and generations of salps were identified and counted. For species identification, Casareto and Nemoto (1987) considered *Salpa thompsoni* and *S. gerlachei* were synonyms to each other. In the present study, we thus treated these two species as *S. thompsoni*. Abundance of salps was calculated from the number of individuals and filtered volume. Carbon weights of salps were estimated using wet and carbon weight relationship after Huntley *et al.* (1989) for *S. thompsoni* and Nishikawa *et al.* (1995) for *Ihlea racovitzai*. For body length (BL: oral-atrial distance) and maturity stages of aggregates and solitaries of *S. thompsoni*, all individuals in the initial or subsamples were examined. The BL was measured to the nearest

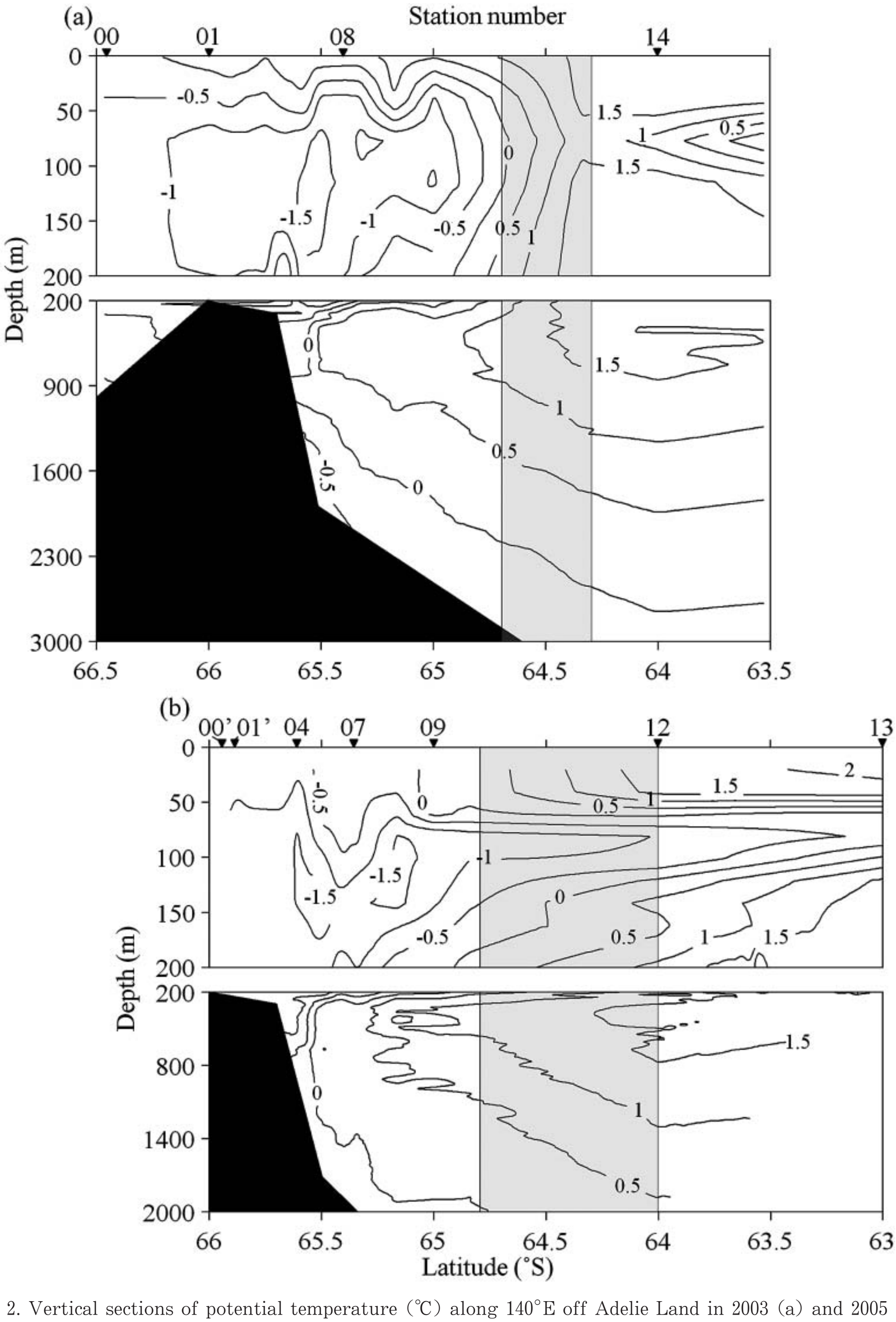

Fig. 2. Vertical sections of potential temperature (℃) along 140°E off Adelie Land in 2003 (a) and 2005 (b). Shaded areas indicate the Southern Boundary of the Antarctic Circumpolar Current.

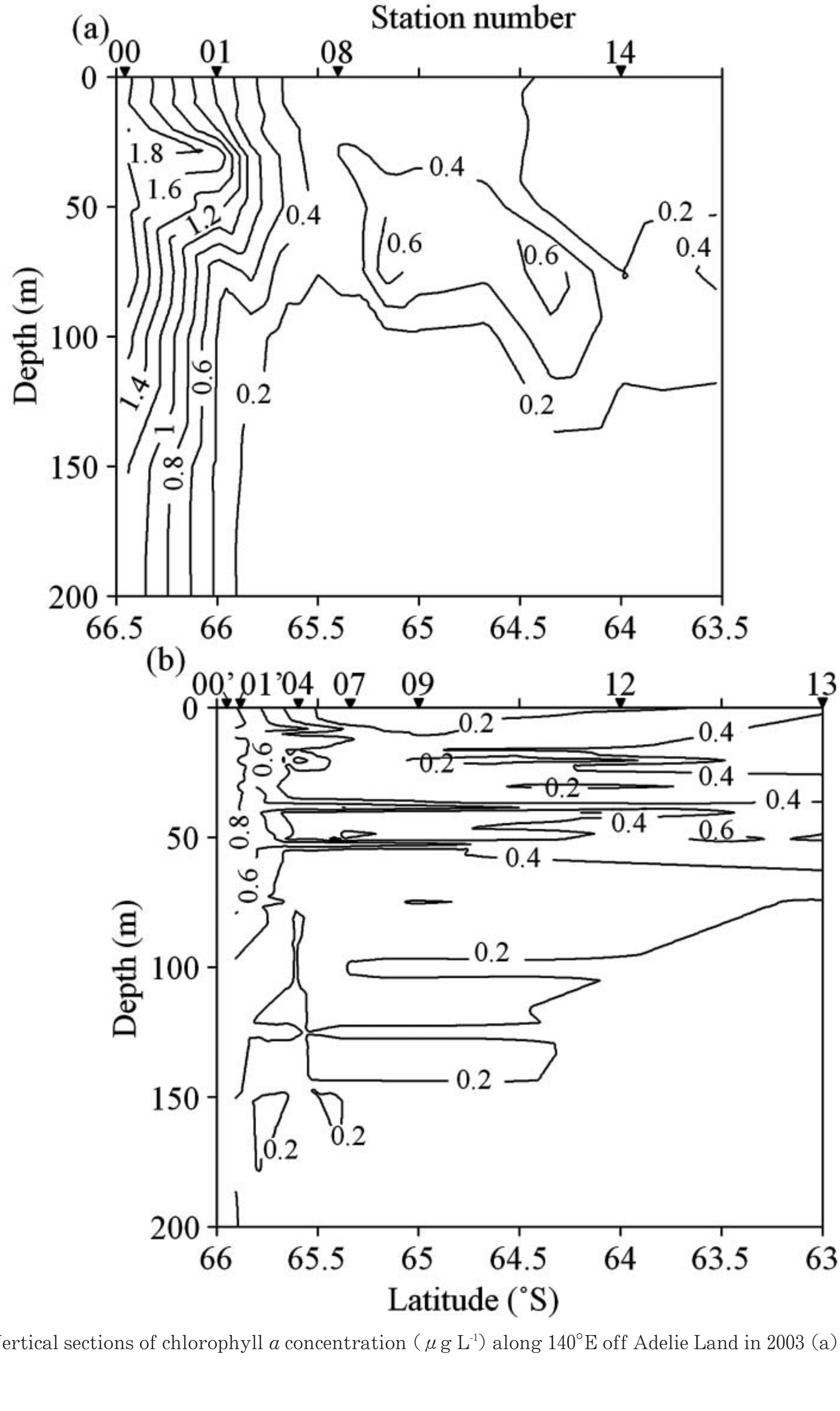

Fig. 3. Vertical sections of chlorophyll *a* concentration ($\mu g\ L^{-1}$) along 140°E off Adelie Land in 2003 (a) and 2005 (b).

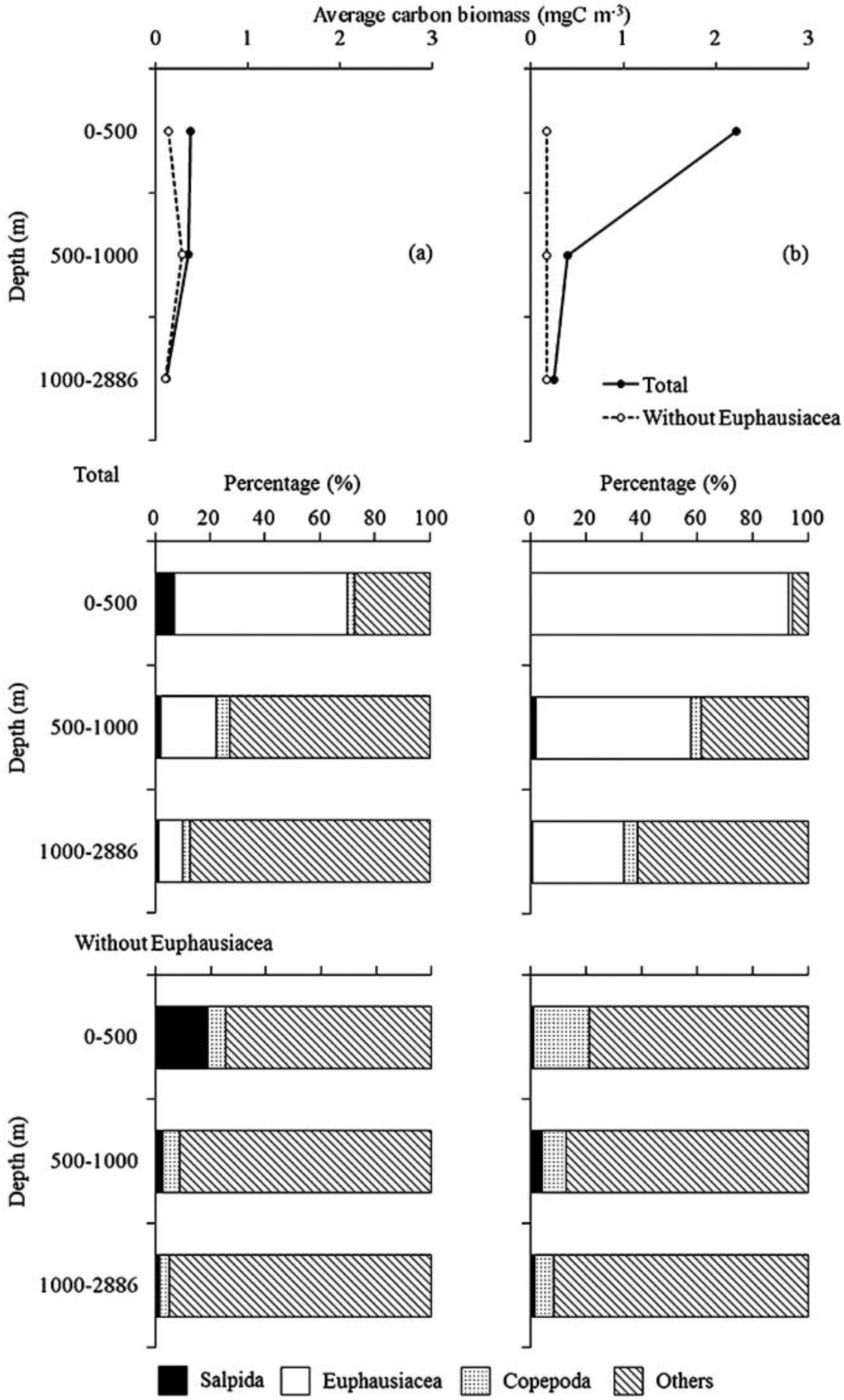

Fig. 4. Vertical distributions of average carbon biomass (top) and relative biomass of major macrozooplankton taxa (middle: all taxa, bottom: without Euphausiacea) off Adelie Land in 2003 (a) and 2005 (b).

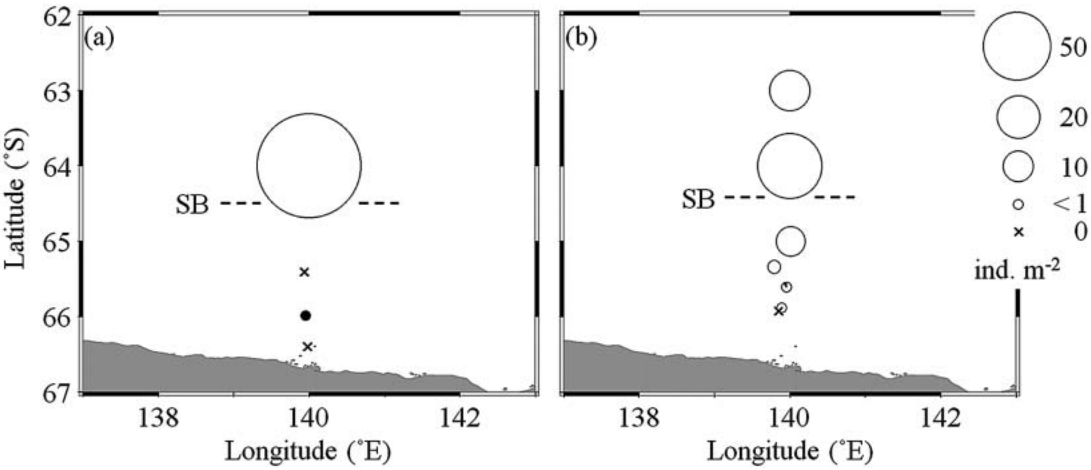

Fig. 5. Horizontal distributions of salps off Adelie Land in 2003 (a) and 2005 (b). SB: the location of the Southern Boundary of the Antarctic Circumpolar Current. Open and solid circles are for *Salpa thompsoni* and *Ihlea racovitzai*, respectively.

1 mm using a caliper. It is known that formalin shrinks the BL of salps (NISHIKAWA and TERAZAKI, 1996). REINKE (1987) reported that the BL of *S. thompsoni* aggregates shrank up to 14.9% of their live length for 15 months after preservation, but NISHIKAWA and TERAZAKI (1996) found, for other salp species (*Thalia democratica*), that the BL became almost constant in about five months of preservation. Because our BL measurements were done after eight months of preservation, considering the BL had been already constant, the BLs in 2003 and 2005 were comparable. In the present study, we thus did not correct the BL shrinkage to compare with previous studies which have not corrected the BL. Maturity stages of *S. thompsoni* aggregates (Table 2) were determined according to the morphological characteristics of the embryo inside an aggregate body following FOXTON (1966). In the present study, we observed individuals with empty and no embryos, and classified them into stage X following CHIBA *et al.* (1999). Although maturity stages of the solitaries (Table 3) were determined according to the morphology of the stolon following FOXTON (1966) who classified new born solitaries into stage 0, in the present study, we combined stages 0 and 1, and defined them as stage 1 because the classification between stages 0 and 1 was difficult due to damage. Stages 4 and spent of the aggregates and over stage 4a of the solitaries were defined as mature stages following CASARETO and NEMOTO (1986), respectively.

Vertical profile as to water temperature at each station was obtained by a CTD (SBE911, Sea-Bird Electronics), except for Stn. C01' in 2005 where CTD observation was not conducted. Alternatively, CTD data from another profiler (ICTD, Falmouth Scientific Inc.) was used for analysis of Stn. C01' in 2005. The CTD observation at Stn. C13 in 2005 was conducted in only upper 200 m due to CTD trouble. The location of the Southern Boundary of the Antarctic Circumpolar Current (SB-ACC) was estimated from potential temperature (θ) following SOKOLOV and RINTOUL (2002). Seawater for chlorophyll *a* concentration (Chl *a*) analysis was sampled by Niskin bottles at each station from 7 to 24 layers between the surface to 200 m; 200 mL of the water sample was filtered through a Whatman GF/F filter; the filter was then soaked in 6 mL N, N-Dimethylformamide to extract chlorophyll *a* pigment (SUZUKI and ISHIMARU, 1990). Chl *a* was then determined by fluorometric method (STRICKLAND and PARSONS, 1972) using a fluorometer (Turner Design 10R).

3. Results

3-1. Environmental conditions

While vertical profile of water temperature

Table 4. Abundance and solitary to aggregate ratio (S/A) of *Salpa thompsoni* in 2003 and 2005.

Station	Abundance (ind. m^{-2})			Solitary/total (%)	S/A
	Aggregate	Solitary	Total		
2003					
C14	95.47	22.64	118.11	19.17	0.24
C08	0.00	0.00	0.00	–	–
C01	0.00	0.00	0.00	–	–
C00	0.00	0.00	0.00	–	–
Average	23.87	5.66	29.53	19.17	0.24
2005					
C13	8.08	9.39	17.47	53.73	1.16
C12	34.33	11.26	45.59	24.70	0.33
C09	6.29	3.06	9.35	32.75	0.49
C07	1.04	0.77	1.81	42.42	0.74
C04	0.74	0.11	0.85	12.50	0.14
C01’	0.01	0.00	0.01	0.00	0.00
C00’	0.00	0.00	0.00	–	–
Average	7.21	3.51	10.73	32.74	0.49

Table 5. Abundance of *Salpa thompsoni* (ind. m^{-2}) in the Southern Ocean.

Location	Date	Sampling depth (m)	Sampling gear	Range	Source
Adelie Land	Feb. 2003 Feb. 2005	0–2886 0–2000	RMT	0–118.1 0–45.6	present study
	Jan.–Feb. 1996	0–200	ORI	Max. 5974.6	Chiba *et al.* (1998)
	Dec. 1994	0–500	ORI-VMPS	156.4–2297.4	Nishikawa and Tsuda (2001)
	Jan. 2002 Feb. 2002 Mar. 2003	0–1000 0–200	RMT	Max. 219.6* Max. 71.6 Max. 3.2	Tanimura *et al.* (2008)
EBS	Apr.–May 2001	0–400	RMT	0–4.8	Pakhomov *et al.* (2006)
SSI	Dec. 1990–Jan. 1991 Jan.–Feb. 1991	0–100	KYMT	0–132.0 0–30.0	Nishikawa *et al.* (1995)
Scotia Sea Elephant Island	Jan.–Feb. 2000 Nov.–Dec. 1994 Dec. 1996	0–200	RMT	Max. 361.2 Max. 8.6 Max. 208.3	Kawaguchi *et al.* (2004)

EBS: Eastern Bellingshausen Sea
SSI: South Shetland Islands
*Calculated as the abundance in the upper 200m

in 2003 showed a relatively warm water mass (≥1.0 ℃) in the north of 65°S (Fig. 2a), such warm water by contrast was extending to the south of 65°S in 2005 (Fig. 2b). The SB-ACC defined by the southern limit of θ_{max} warmer than 1.5 ℃ (SOKOLOV and RINTOUL, 2002) was located between 64°20′ and 64°40′S in 2003, and between 64° and 64°50′S in 2005 (Figs. 2a, b). In 2003, Chl *a* generally was increasing toward the south (Fig. 3a). Mean Chl *a* in the upper 200 m ranged between 0.13 and 1.75 μg L^{-1}. In 2005, mean Chl *a* in the upper 200 m was lower (0.14–0.67 μg L^{-1}; Fig. 3b) than in 2003.

3-2. Carbon biomass of macrozooplankton

The macrozooplankton biomasses in 2003 were higher in 0–500 m and 500–1000 m (0.38 ±0.07 and 0.36±0.05 mgC m^{-3}, respectively; Fig. 4a) than in 1000–2886 m. Excluding Euphausiacea, the biomass was reduced in 0–500 m. Salps occupied 1.5–7.0% of the biomass, and especially abundant in 0–500 m (Fig. 4a).

In 2005, total zooplankton biomass peak was seen in 0–500 m (2.22±0.61 mgC m^{-3}; Fig. 4b), where Euphausiacea dominated. The contribution of salps increased in 500–1000 m (1.9%; Fig. 4b).

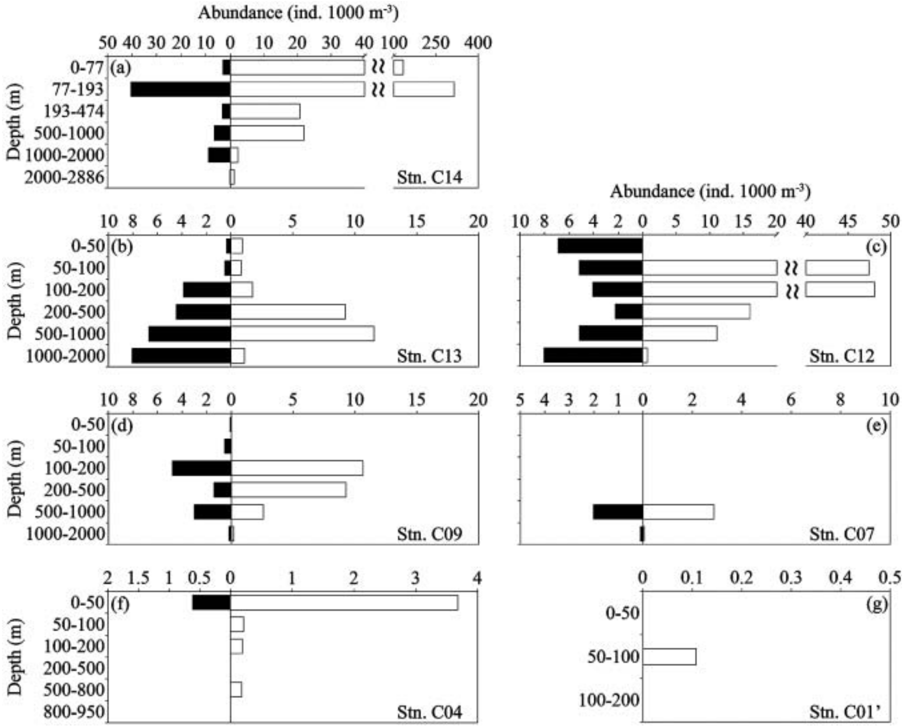

Fig. 6. Vertical distributions of *Salpa thompsoni* off Adelie Land in 2003 (a) and 2005 (b–g). Open bars: aggregate, solid bars: solitary.

3-3. Horizontal and vertical distribution of salps

Two species of salps, *Salpa thompsoni* and *Ihlea racovitzai*, were observed and the former numerically dominated in 2003 and 2005 (Fig. 5). In 2003, *S. thompsoni* occurred only at Stn. C14 located in the north of the SB-ACC (118.1 ind. m^{-2}; Fig. 5a). Solitaries comprised 19.2% of *S. thompsoni*; solitary to aggregate ratio being 0.24 (Table 4). Conversely, *I. racovitzai* occurred only at Stn. C01 located in the south of the SB-ACC (0.2 ind. m^{-2}; Fig. 5a). In 2005, *S. thompsoni* abundance was lower than that of 2003 (Table 4). *S. thompsoni* occurred at all stations except for Stn. C00' (Fig. 5b). Many *S. thompsoni* were observed in the north of 65°S, with the highest abundance at Stn. C12 near the SB-ACC (45.6 ind. m^{-2}). Solitaries were distributed at five stations (Stns. C13, C12, C09, C07 and C04); solitary to aggregate ratio ranging from 0.14 (Stn. C04) to 1.16 (Stn. C13) (Table 4). *I. racovitzai* occurred only at Stn. C04 located in the south of SB-ACC (0.1 ind. m^{-2}; Fig. 5b) along with the distribution pattern of 2003. *S. thompsoni* abundance in the present study was lower than that in the same season reported by Chiba *et al.* (1998), Kawaguchi *et al.* (2004) and Tanimura *et al.* (2008) but higher than that in autumn (Pakhomov *et al.*, 2006; Tanimura *et al.*, 2008) (Table 5).

In 2003, *S. thompsoni* was observed between the surface and 2886 m (Fig. 6a). The aggregates and solitaries densely occurred in the 77–193 m (315.0 and 40.5 ind. 1000 m^{-3}, respectively). In 2005, *S. thompsoni* was distributed at almost every sampling layer at Stns. C13, C12 and C09 (Figs. 6b–d). At Stn. C07, both aggregates and solitaries were observed in layers lower than 500 m depth (Fig. 6e). At Stn. C04, the aggregates occurred between the surface and 800 m. On the other hand, solitaries were observed only in 0–50 m (Fig. 6f). Only aggregates occurred in 50–100 m at Stn. C01' (Fig. 6g). *I. racovitzai* was observed in the upper 200 m both in 2003 and 2005 (figure not shown).

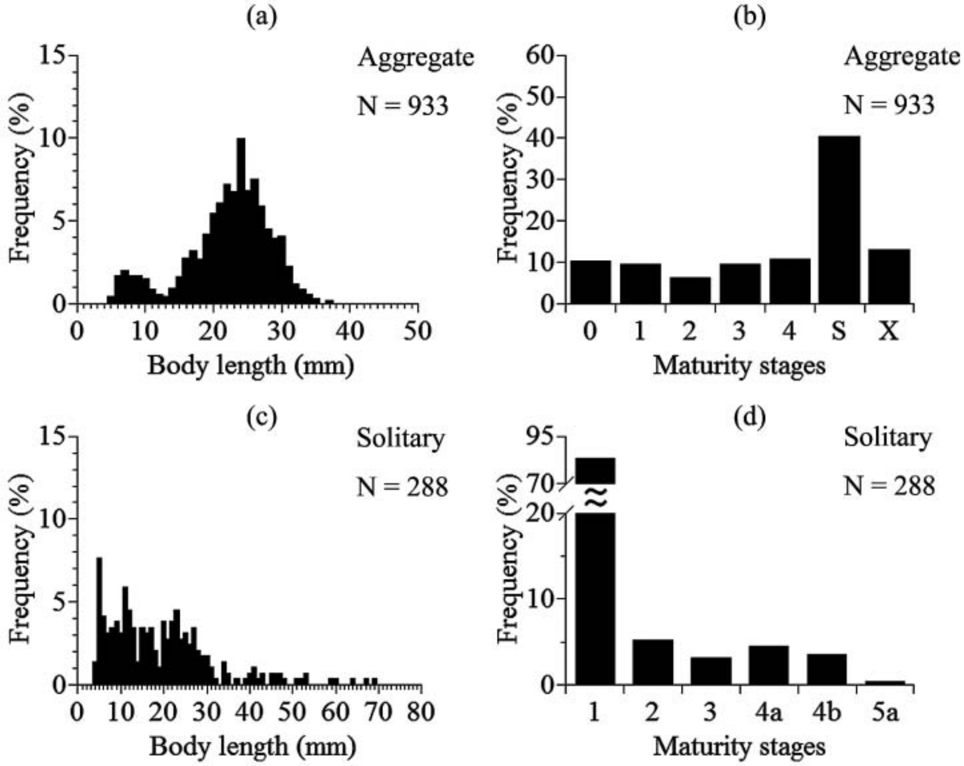

Fig. 7. Body length frequency and maturity stages of *Salpa thompsoni* aggregate (a, b) and solitary (c, d) off Adelie Land in 2003. N: number of measured individuals, S: stage spent, X: stage X.

3-4. Population structure of *Salpa thompsoni*

In 2003, BL of *S. thompsoni* aggregates ranged between 5 and 37 mm with two peaks at 7 mm and 24 mm (Fig. 7a). Mature stages (stage 4 and spent) predominated, accounting for 51.2%, and stage X occupied 13.0% of all aggregates (Fig. 7b). As to the solitaries, the BL ranged from 4 to 69 mm; of all solitaries, small individuals (<30 mm BL) comprised 85.8% (Fig. 7c). While the number of mature solitaries (over stage 4a) were small (8.3%), immature individuals (stage 1–3) predominated, accounting for 91.7% of all solitaries (Fig. 7d). In 2005, the size of the aggregates ranged from 4 to 38 mm (Fig. 8a). Early maturity stages (0–2) predominated comprising 68.8%, and stage X occupied 4.8% of all aggregates (Fig. 8b). The solitaries ranged from 5 to 63 mm BL (Fig. 8c). The youngest stage (stage 1) dominated (comprising 62.4%) while mature solitaries contributed 16.2% of all solitaries (Fig. 8d). As to the density weighted length frequency distribution of *S. thompsoni* population included in both aggregates and solitaries in 2003 and 2005, the modal lengths were 24 mm (Fig. 9a) and 8 mm (Fig. 9b), respectively.

Mature aggregates of *S. thompsoni* mainly occurred in 500–1000 m at Stns. C13 and C12 in 2005 (8.9 and 7.7 ind. 1000 m^{-3}, respectively; Figs. 10a, c). Immature aggregates were abundant in the upper 500 m at Stns. C13, C12 and C09 (max. 7.0, 46.5 and 9.1 ind. 1000 m^{-3}, respectively; Figs. 10a, c, e). As to solitaries, mature individuals mainly distributed in the upper 500 m. In contrast, immature solitaries densely occurred in deeper layers (500–2000 m) at Stns. C13, C12 and C09 (Figs. 10b, d, f).

The average body length of *S. thomsponi* solitaries decreased with increasing depth at Stns. C13, C12 and C09 in 2005 (Figs. 11a–c). Although a change of the average length of *S. thompsoni* aggregates on the sampling layers was not observed at Stn. C13 (Fig. 11a), large-size aggregates constituted the deeper layer

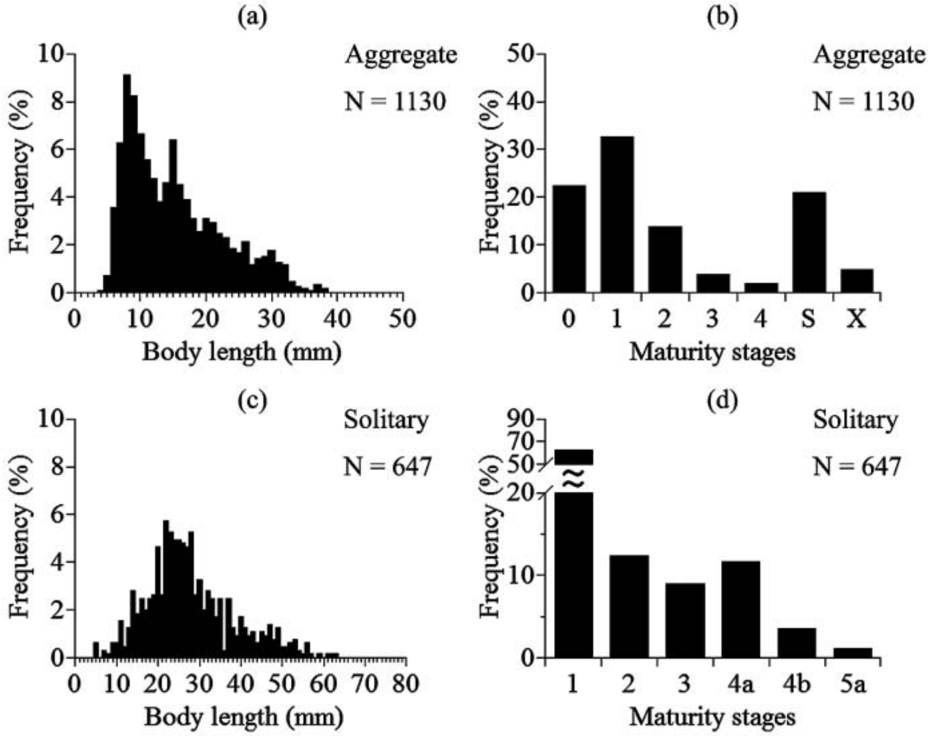

Fig. 8. Body length frequency and maturity stages of *Salpa thompsoni* aggregate (a, b) and solitary (c, d) off Adelie Land in 2005. N: number of measured individuals, S: stage spent, X: stage X.

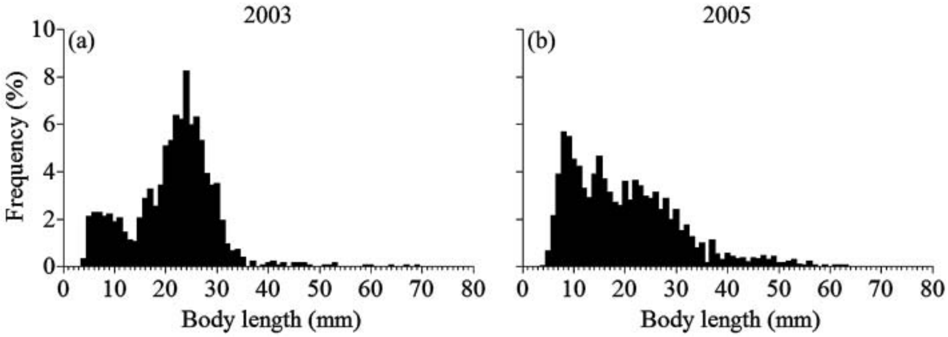

Fig. 9. Density weighted length frequency distributions of *Salpa thompsoni* population (aggregate + solitary) in 2003 (a) and 2005 (b).

population at Stns. C12 and C09 (Figs. 11b, c).

The compositions of *S. thompsoni* maturity stages were different at each station in 2005 (Fig. 12). Both mature aggregates and solitaries were observed at Stns. C13, C12 and C09. At Stn. C07, mature solitaries were absent while mature aggregates occurred. Both aggregates and solitaries were composed of immature individuals at Stn. C04, only immature aggregates were observed at Stn. C01'.

4. Discussions

4-1. Distribution of *Salpa thompsoni* in relation to oceanographic conditions

Our result agrees with the previous report by CASARETO and NEMOTO (1986) showing *Ihlea racovitzai* was distributed at higher latitude than *Salpa thompsoni*.

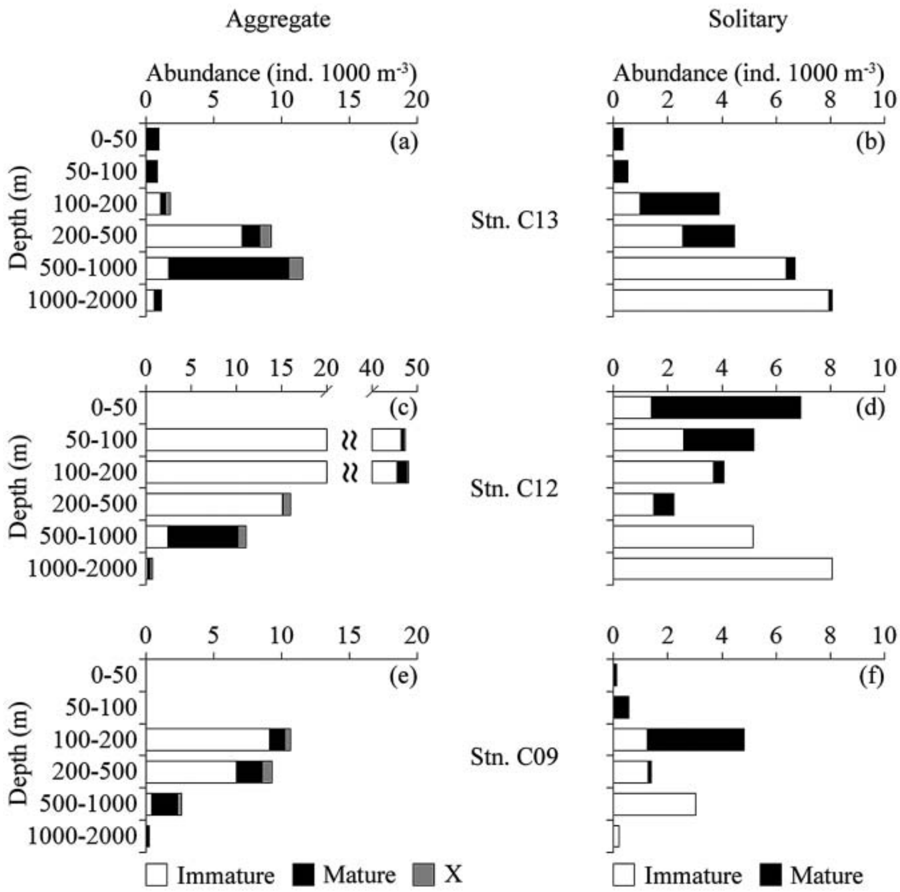

Fig. 10. Vertical distributions of immature and mature *Salpa thompsoni* at Stns. C13 (a, b), C12 (c, d) and C09 (e, f) off Adelie Land in 2005.

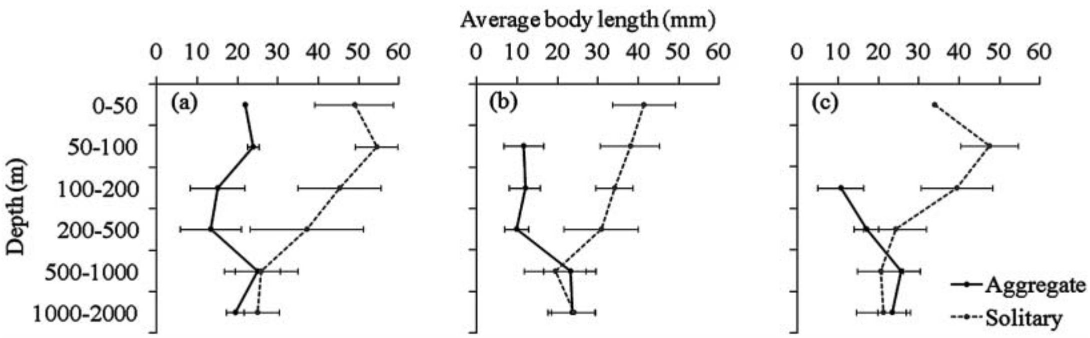

Fig. 11. Average body length (mm) of *Salpa thompsoni* aggregate and solitary at Stns. C13 (a), C12 (b) and C09 (c) off Adelie Land in 2005. Horizontal bars range standard deviations.

We observed that *S. thompsoni* in 2005 was distributed at higher latitude than in 2003 (Fig. 5). Previous reports have shown that *S. thompsoni* occurred at high latitudes off Adelie Land in the Southern Ocean (CASARETO and NEMOTO 1986; CHIBA *et al.*, 1998, 1999; NICOL *et al.*, 2000; TANIMURA *et al.*, 2008). PERISSINOTTO and PAKHOMOV (1998) reported that *S.*

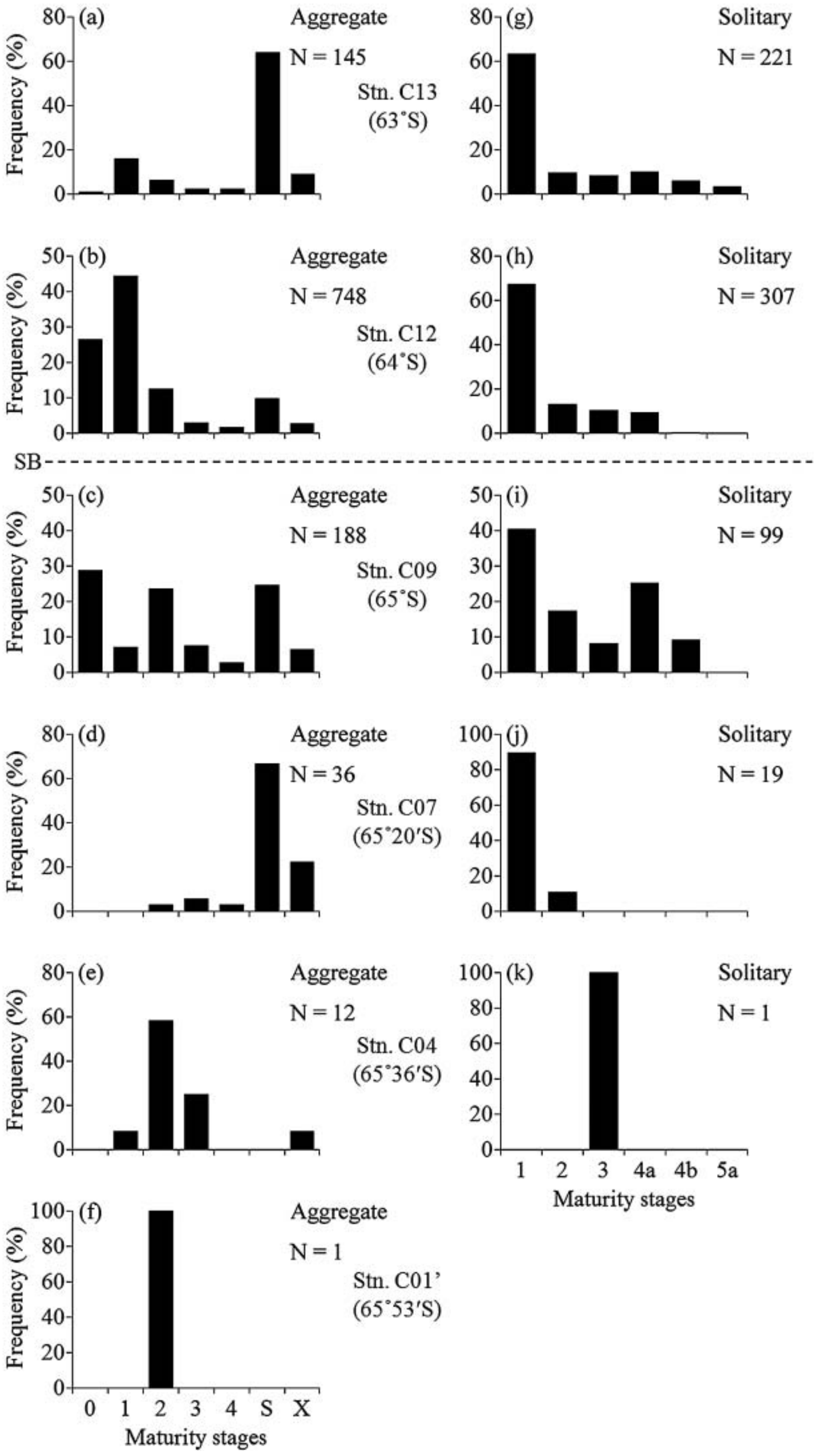

Fig. 12. Latitudinal changes of maturity stages of *Salpa thompsoni* aggregate (a–f) and solitary (g–k) off Adelie Land in 2005. N: number of measured individuals, S: stage spent, X: stage X, SB: Southern Boundary of the Antarctic Circumpolar Current.

thompsoni population collapses because of a dramatic reduction in *S. thompsoni* feeding rate when Chl *a* exceeds 1.0 $\mu g\ L^{-1}$. In the present study, however, mean Chl *a* in the upper 200 m both in 2003 and 2005 was less than 1.0 $\mu g\ L^{-1}$ except for Stn. C00 in 2003, suggesting that distribution of *S. thompsoni* was not limited by Chl *a*. Previous studies have clarified that *S. thompsoni* occurred mainly in the warm water and was found in the north of the SB-ACC (FOXTON, 1966; NICOL *et al.*, 2000; PAKHOMOV *et al.*, 2006; TANIMURA *et al.*, 2008). CHIBA *et al.* (1999) indicated that the southernmost *S. thompsoni* population might occur only occasionally in mid-summer due to advection when the ice edge retreats to its minimum extent. The relatively warm water (≥1.0 ℃) extended to the south of 65°S in 2005 (Fig. 2), suggesting that *S. thompsoni* was transported from a northern area to the south of the SB-ACC.

4-2. Interannual change of *Salpa thompsoni* population strucutre

The abundance of *Salpa thompsoni* in 2005 was lower than that in 2003 (Table 4) and those from various areas in the summer (Table 5). The modal length of *S. thompsoni* population in 2005 (8 mm) was smaller than that in 2003 (24 mm) and coincided with that in March (8 mm) reported by TANIMURA *et al.* (2008). PAKHOMOV *et al.* (2006) reported the population in the autumn consisted of early maturity stages (0–2) of the aggregates and the young (stage 2) solitaries with 29–32 mm. The population structure of 2005 in the present study was similar to that of PAKHOMOV *et al.* (2006). Maximum solitary to aggregate ratio in 2005 was 1.16. Since the major driver of the salp bloom is the asexual budding of up to 800 buds originating from a solitary of *S. thompsoni* (DAPONTE *et al.*, 2001), high solitary to aggregate ratio indicates low reproduction (TANIMURA *et al.*, 2008). CHIBA *et al.* (1999) found the reproduction of *S. thompsoni* was reduced in autumn. The reproductive condition of *S. thompsoni* population in 2005 was similar to that in autumn, which season was considered as the end of reproduction.

4-3. Horizontal and vertical changes in population structure of *Salpa thompsoni*

We observed that the vertical distributions of immature and mature *S. thompsoni* were different at Stns. C13, C12 and C09 in 2005 (Fig. 10). The greater abundances of immature aggregates and mature solitaries occurred in the upper 500 m, suggesting that the solitary were asexually reproducing. Conversely, the abundances of mature aggregates and immature solitaries increased in the deeper layer. This reveals the young solitaries were sexually reproduced by mature aggregates in the deeper layer. FOXTON (1966) reported the young solitaries predominated in the deeper layer and kept their stocks during autumn and winter. It is thus considered that the small immature solitaries in the deeper layer overwintered.

FOXTON (1966) clarified seasonal changes in the maturity stages of *S. thompsoni* and reported the ontogenetic vertical migration of this species. CASARETO and NEMOTO (1986) observed the different vertical distribution of immature and mature individuals in the summer population of *S. thompsoni*. As with these previous reports (FOXTON, 1966; CASARETO and NEMOTO, 1986), the result of the present study suggests *S. thompsoni* are ontogenetic vertical migrators.

Generally, salps have a life cycle in which the sexual generation alternates with the asexual generation (GODEAUX *et al.*, 1998). This means life cycle of salps cannot be completed if individuals do not reproduce in both generations. CASARETO and NEMOTO (1986) reported the latitudinal variation of *S. thompsoni* population structure and linked poor reproductive performance at high latitude to the low water temperature. CHIBA *et al.* (1999) suggested that the *S. thompsoni* population at high latitude cannot complete its life cycle due to low temperature and scarcity of food. In 2005, mature individuals of both aggregates and solitaries of *S. thompsoni* were observed in the north of 65°S (Stns. C13, C12 and C09), suggesting that the life cycle there was completed. On the other hand, no mature individuals of aggregates and/or solitaries occurred, and *S. thompsoni* abundance declined in the south of 65°20′S (Stns. C07, C04 and C01'). The low temperature water (<0℃) was observed in the south of 65°20′S. Therefore, it is very likely that *S. thompsoni* in this area were not reproducing because of low temperature and so they could not complete their life cycle, which suggested a collapse of the *S. thompsoni* population. However, temperature effects on reproductive success/failure of *S. thompsoni* have never been reported, which issue being remained to be investigated by future studies.

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Development of Algorithms for Estimating the Seasonal Nitrate Profiles in the Upper Water Column of The Sagami Bay, Japan

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Abstract: We propose a method to estimate nitrate (NO_3^-) profiles in the upper water column of the Sagami Bay, Japan, using surrogate oceanographic data such as temperature, salinity and chlorophyll *a* (Chl *a*). Analysis of a 10 year (June 1999-November 2008) dataset revealed that variations in nitrate profiles were associated with seasonal variations of water column structure in the upper 200m of the Sagami Bay. The upper 200m water column structure could be separated into three layers; the surface mixed layer, the intermediate layer, and the deeper layer. The surface mixed layer showed distinct seasonal variability in depth, while the deeper layer than $\sigma_\theta = 26$, located at depths between 130-160m, showed little seasonal variability. Warm and less saline water in the surface mixed layer and the upper intermediate layer during summer and fall indicated that this water was influenced by seasonal heating and freshwater input, and the large variation at these depths indicated the spatial heterogeneity of the water. When the seasonal variability of nitrate and its predictor variables was taken into account, nitrate concentrations in the upper two layers could be reproduced for each season on the basis of temperature and Chl *a*. In the deeper layer, nitrate could be explained without seasonal classification on the basis of temperature and salinity. The empirical algorithms for nitrate in the three layers were used to construct nitrate profiles for four seasons in the Sagami Bay. When the performance of the algorithm was tested against an independent data set, the coefficient of determination and root mean square difference between measured and estimated nitrate in each season ranged between 0.92～0.98 and 1.3～1.6 μM, respectively.To our knowledge, this is the first study that demonstrates that nitrate profiles in the upper 200m coastal oceanic waters can be reproduced based on temperature, salinity and Chl *a* data. These latter datasets are now routinely measured on various platforms, such as ships, floats, gliders, and buoys, using CTD and Chl *a* sensors and hence these algorithms could greatly aid in biogeochemical cycle studies in the oceanic environments, especially in highly dynamic coastal regions.

Keywords: *nitrate algorithm, mixed layer depth, water mass, Sagami Bay-Japan.*

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1. Introduction

Light and nutrients are major factors controlling phytoplankton growth in the upper layer of the ocean (PARSONS *et al.*, 1977; ARRIGO, 2005). Nitrate (NO_3^-) in particular is important because it is a main source of nitrogen supporting new production (DUGDALE and GOERING, 1967) and because in general in many of the world's oceans, phytoplankton biomass in the upper water column is strongly regulated by nitrate availability (FANNING, 1989; LEVITUS *et al.*, 1993). The availability of nitrate in the euphotic zone is strongly regulated by vertical mixing and advective supply of nitrate to the upper euphotic layers of the ocean, both of which in turn are influenced by variations of environmental forcing, such as solar heating, wind stress, and/or intrusion of different water masses (PRICE *et al.*, 1986; MARRA *et al.*, 1990). Despite its importance, quantitative estimates of nitrate concentrations are limited because of the logistical difficulties in measuring nitrate temporally and spatially by conventional ship observations. There have been attempts to estimate nitrate by automated nitrate sensors on moorings or profiling floats (JOHNSON *et al.*, 2006), but limitations in sensor availability have been a major impediment to these measurements becoming routine.

Previous studies showed a strong negative correlation between temperature and nitrate, a reflection of the processes of nutrient supply from the deep into the mixed layer (KAMYKOWSKI, 1987; GARSIDE and GARSIDE, 1995). This correlation has been used in a number of recent studies for estimating nitrate concentrations in surface water using remotely sensed sea surface temperature (SST) (KAMYKOWSKI and ZENTARA, 1986; GARSIDE and GARSIDE, 1995; GONG *et al.*, 1995; KAMYKOWSKI *et al.*, 2002; SWITZER *et al.*, 2003). The use of temperature alone as a surrogate to estimate nitrate is, however, limited in areas where phytoplankton activity is high (GOES *et al.*, 1999; 2000). This is especially true in high to mid latitude regions, where short lived bursts of phytoplankton growth, such as during spring or during bloom formation, can have a strong influence on nitrate availability. To account for biological activity, GOES *et al.* (1999, 2000) proposed the use of chlorophyll *a* (Chl *a*) as an additional determinants of nitrate, and showed that its addition could greatly improve the nitrate estimation in the surface ocean.

Since the empirical algorithms of GOES et al, (1999, 2000) were meant for use with satellite data, they were limited to the surface and relied primarily on satellite derived fields of SST and Chl *a*. Here we describe an approach to estimate nitrate concentration from the surface to the ocean's interior (200 m depth). The method uses temperature, Chl *a* and salinity as predictor variables to estimate nitrate concentration not only in the surface but also in the subsurface layer (e.g. below euphotic zone) of water column. We show that the algorithms, when applied to CTD and Chl *a* data that are now routinely derived from moorings and profiling platforms, can be extremely useful to understand nitrate variability in highly dynamic coastal environments, such as the Sagami Bay. The bay is situated on the east coast of Honshu Island, Japan and in a region that comes under the influence of several source waters including the Kuroshio current water.

2. Methods and Data

2.1 Study Site

Sagami Bay, located in the southeastern part of Honshu Island, Japan, has a wide mouth open toward the Pacific Ocean (Fig. 1A). The water in the bay is influenced by both the Kuroshio current water and the coastal waters. IWATA (1985) and more recently HINATA *et al.* (2005) found that the offshore water between the Kuroshio front and Honshu Island, which originates outside of the bay, influences surface water in the bay. Intermediate Oyashio water, which has low temperature (<7.0℃), low salinity (34.2) and high dissolved oxygen concentration (>3.5 ml l^{-1}), sometimes intrudes into the bay at depth along the isopycnal surface of $\sigma_\theta = 26.8$ (SENJYU *et al.*, 1998). The water in the bay also frequently exchanges with both Tokyo Bay and Pacific Ocean as observed by YANAGI and HINATA (2004).

2.2 Data Sources

Development of the empirical algorithms was

Table 1. Data sources for constructing the nitrate algorithms

No	Data Sources	Cruises / Date	Number of Profiles
1	*T/V* Seiyo Maru	Monthly Time Series (June 1999–Sept 2007) except: Oct 1999; Nov 2001; Jan–Feb 2002; Jan 2004	95
2	*R/V* Tansei Maru	a. 2004	12
		- KT 04–04 (23–25 April)	7
		- KT 04–11 (8–12 June)	7
		- KT 04–15 (31 July–2 Aug)	
		b. 2006	13
		- KT 06–08 (2–4 May)	
		c. 2007	4
		- KT 07–10 (18–20 May)	28
		- KT 07–17 (19–26 July)	23
		- KT 07–30 (13–20 Nov)	
		d. 2008	8
		- KT 08–01 (20–23 Feb)	10
		- KT 08–05 (1–7 April)	22
		- KT 08–15 (6–10 July)	21
		- KT 08–24 (23–27 Sept)	6
		- KT 08–29 (6–10 Nov)	
3	JODC	September, 1996	6

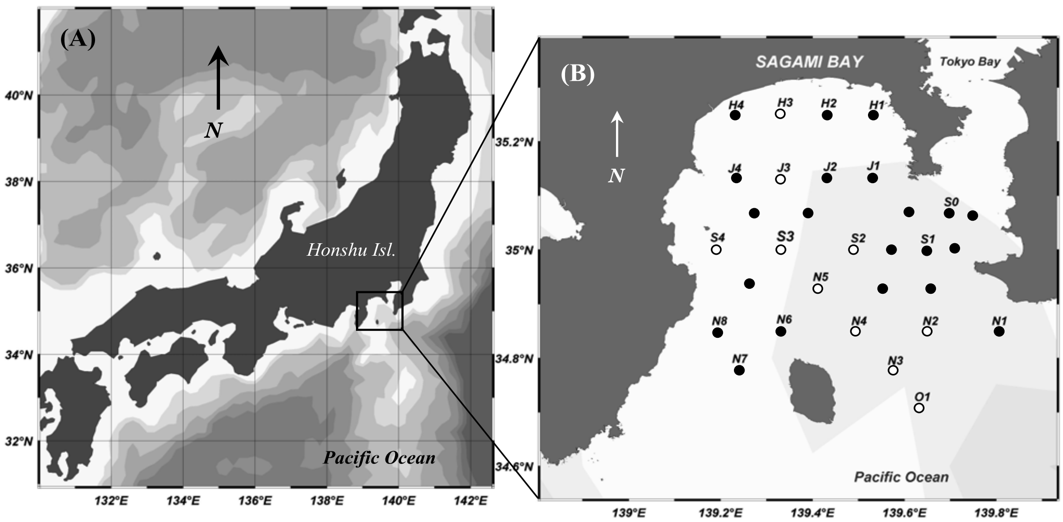

Fig. 1. Maps of Japan (A) and Sagami Bay (B) with the sampling stations of nitrate, CTD and Chl *a*. Stations indicated by white circles represent the sampling points of independent data sets used for the algorithm validation.

undertaken using temperature, salinity, nitrate and Chl *a* from surface to 200m depths from the following data sources (Table 1) : (1) long term monthly cruises from 1999-2007 at Stn. S3 by *T/V* Seiyo Maru of Tokyo University of Marine Science and Technology, (2) cruises carried out by Nagoya University by using *R/V* Tansei Maru for collecting data at many stations in the entire bay, and (3) Japan Oceanographic Data Center (JODC). A fraction of the data from (2), not used for constructing the algorithm, was used as independent data set to test the performance of the algorithms that were generated (Table 2,

Table 2. Independent data sources for testing the algorithms performance.

No	Cruise	Stations	Number of Profiles	Seasons
1	KT08–01	S3, H3, J3, N5	4	Winter
2	KT08–05	S3, N3, N4, J3, H3, O1	6	Spring
3	KT08–15	H3, J3, N3, S3	4	Summer
4	KT07–30		6	Fall
	KT08–29	S3, H3, J3, N3, N4, N5		

Fig. 1B).

During cruises (1) and (2), seawater samples were collected with 5 or 10L Niskin samplers mounted as a rosette around a CTD (I-CTD and NXIC-CTD, Falmouth Scientific-INC). Samples for nitrate and Chl *a* were collected at discrete depths in the water column from the surface (5m or 10m) to 200 m water depths. Sampling depths were not always consistent for each cruise. Samples for nitrate were stored in polystyrene bottles, frozen immediately after the collection and stored at −20℃ until analysis. Nitrate concentrations in water sample collected by *T/V* Saiyo Maru and *R/V* Tansei Maru were measured by auto-analyzers AACS III and TRAACS 2000 (Bran and Luebbe), respectively (HASHIMOTO *et al.*, 2005). Chl *a* in samples were measured by filtering 200 ml water samples onto 25 mm Whatman GF/F filters. Chl *a* was immediately extracted by immersing the filter into *N, N*-dimethylformamide (SUZUKI and ISHIMARU, 1990) under cold and dark conditions, for at least 24 hours prior to the analysis. Chl *a* concentrations were determined using a Turner Design Model 10-AU fluorometer calibrated with standard Chl *a* (Wako Pure Chemical Industries), according to the method of WELSCHMEYER (1994).

2.3. Data Analysis

The database used for constructing the algorithms for nitrate yielded 262 profiles of temperature, salinity, nitrate and Chl *a* in the upper 200m layer. Nitrate and Chl *a* profiles consists of 8–12 sampling depth points, which varied among the different cruises, while temperature and salinity profiles were measured continuously by using a CTD and used for deriving water density gradients. The total number of data points containing temperature, salinity, Chl *a* and NO_3^- was 3324. The mixed layer depth (MLD) was established based on a difference in water density of 0.125 from the surface layer (LEVITUS, 1982). The data from the long term monthly cruises at Stn. S3 by *T/V* Seiyo Maru were used for the analysis of seasonal variability.

Relationship between nitrate concentration and its predictor variables were analyzed by multiple linear regression analysis. The predictive accuracy of the regression model was characterized using root mean square error (RMSE) with data numbe of *N* (KAMYKOWSKI *et al.*, 1986; GARSIDE and GARSIDE, 1995; GOES *et al.*, 1999 and 2000; SWITZER *et al.*, 2003);

$$RMSE=\sqrt{\frac{1}{N}\sum_{i=1}^{N}(NO_{3estimated}-NO_{3measured})^2}, \quad (1)$$

where $NO_{3estimated}$, and $NO_{3measured}$ is estimated and measured nitrate concentration (μM) for sample *i*, respectively.

3. Results

3.1. Water Column Structure of the Upper 200 m of Sagami Bay.

As shown in the T-S diagram from the archived data of Sagami Bay (Fig. 2A), the temperature and salinity ranged from 8.9–28.5℃ and 32.1–34.7, respectively. It is clearly seen that the denser deeper water showed less variability in temperature and salinity compared to the less dense upper water column waters. Figs. 2B-E show the seasonal variability associated with Fig. 2A, indicating that the higher temperature and less saline shallow waters in summer and fall. It is important to note that the denser water (σ_θ>24.3) had little variability in salinity and fell onto a line on the T-S diagrams (Figs. 2A-E), particularly below the water with σ_θ of 26. This σ_θ of 24.3 and 26 also nearly corresponded to the density of the surface water during winter and spring and

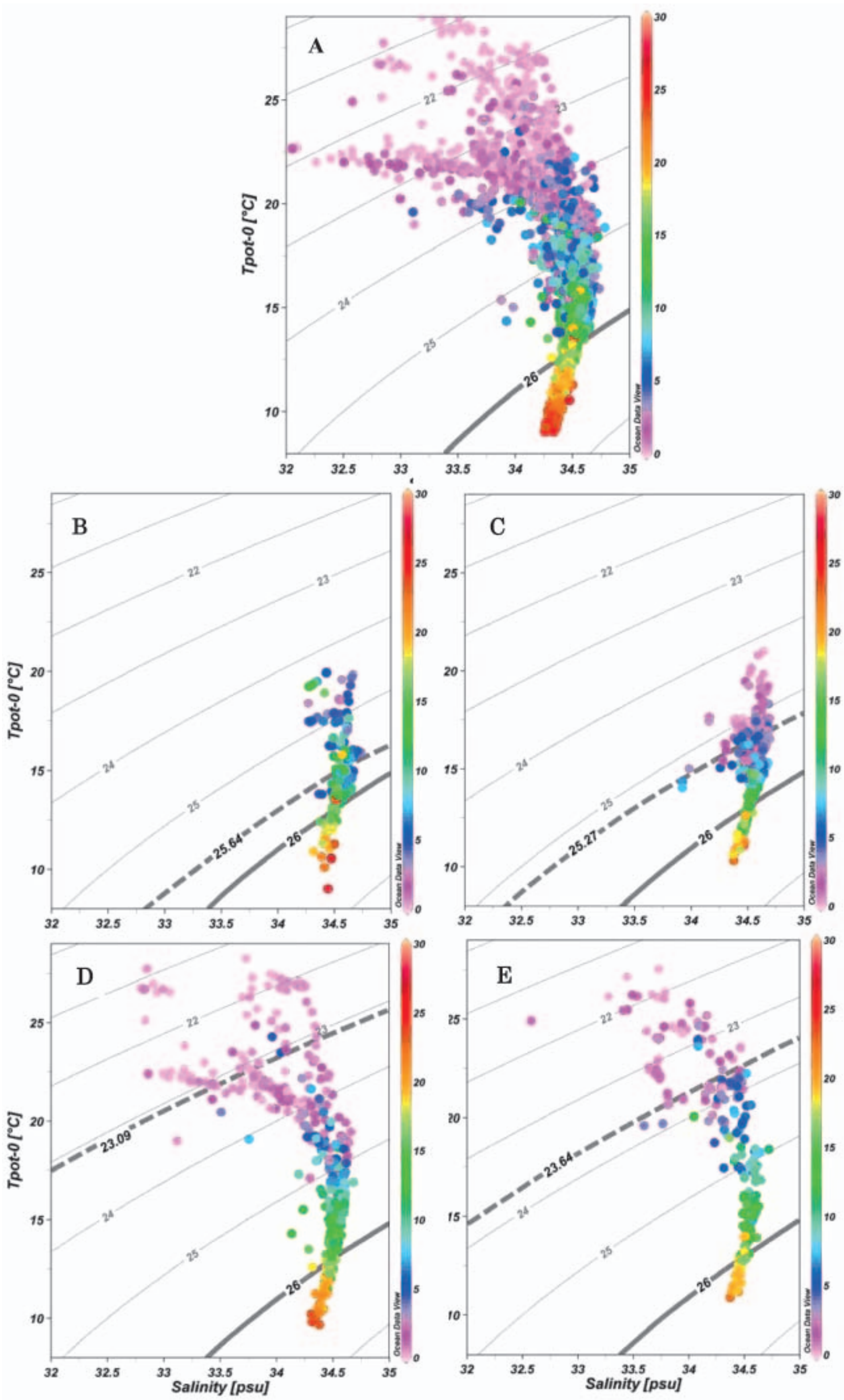

Fig. 2. The T-S diagrams of the upper 200m waters in Sagami Bay for all seasons (A), winter (B), spring (C), summer (D) and fall (E). The color bar represents nitrate concentration (μM). The thick lines correspond to the $\sigma_\theta = 26$ isopycnal surface and the thick dotted line shows the average water density of MLD waters in each season.

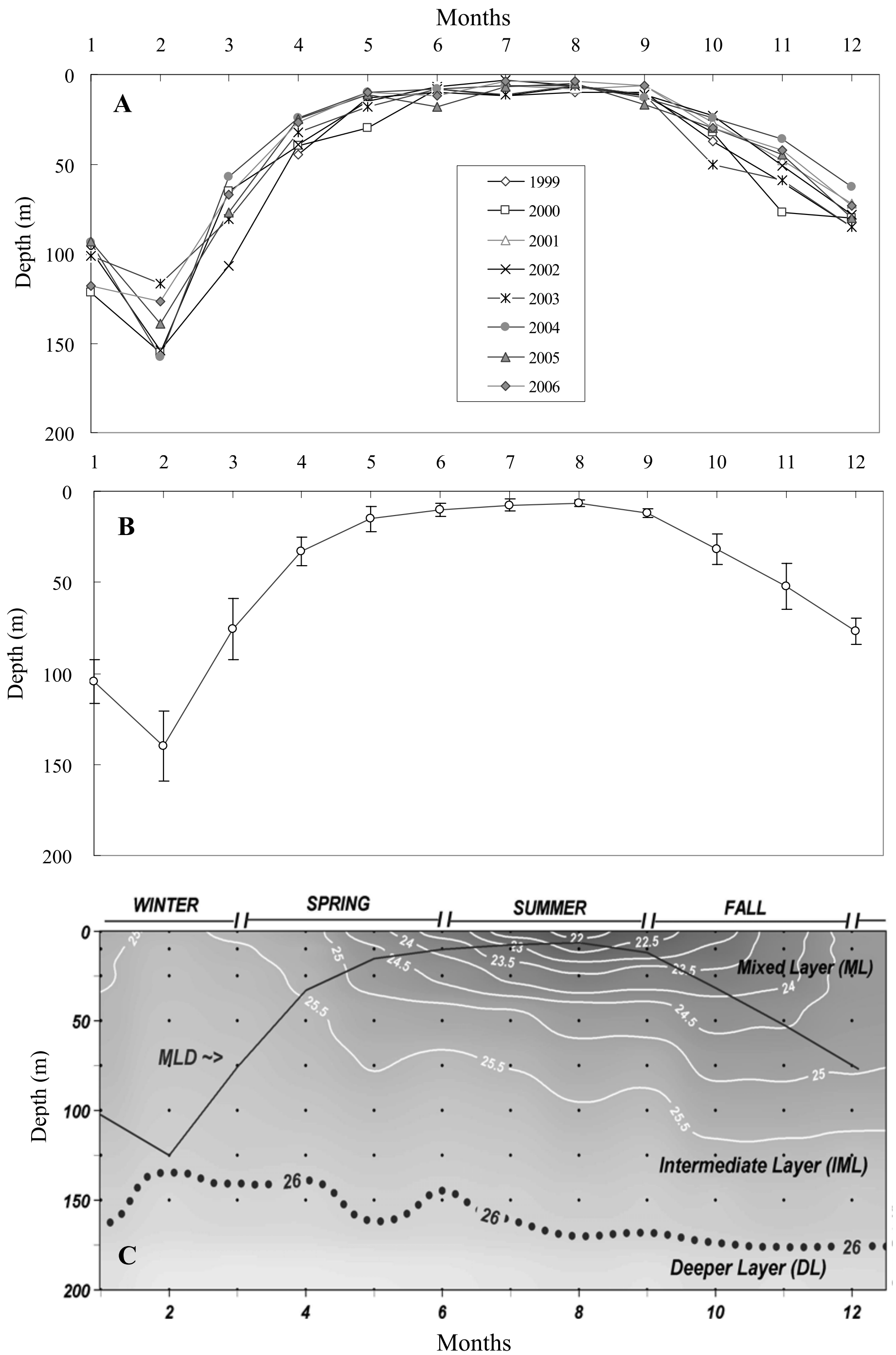

Fig. 3. Seasonal variation of mixed layer depth (A) and the average with standard deviation (B) at stn. S3 in Sagami Bay from 1999 to 2006. Seasonal density structure of the upper 200m water column of Stn. S3 (C). Dot and solid lines indicate $\sigma_\theta = 26$ and bottom of the mixed layer, respectively. The top layer is named as mixed layer (ML), and the second layer is the intermediate layer (IML), and the last layer is the deeper layer (DL).

Table 3. Correlation coefficient (r) between nitrate and its predictor variables in mixed layer water, intermediate water, and deeper water. n is number of data points.

NO	Predictors	Winter	Spring	Summer	Fall
Mixed Layer		n=212	n=215	n=87	n=242
1	Temperature	-0.49**	-0.68**	-0.35*	-0.91**
2	LogTemperature	-0.49**	-0.68**	-0.36*	-0.91**
3	Chlorophyll*a*	0.45**	0.51**	0.17	0.68**
4	Salinity	0.07	0.01	0.03	0.49**
Intermediate Layer		n=222	n=255	n=1183	n=243
5	Temperature	-0.71**	-0.86**	-0.94**	-0.93**
6	Log Temperature	-0.71**	-0.85**	-0.95**	-0.93**
7	Chlorophyll *a*	0.69**	0.48**	0.48**	0.63**
8	Salinity	0.69**	0.45**	0.24	0.23
Deeper Layer		n=665			
9	Temperature	-0.87**			
10	Log Temperature	-0.87**			
11	Chlorophyll *a*	0.05			
12	Salinity	0.85**			

** $p < 0.001$; * $p < 0.05$

bottom of the winter mixed layer, respectively. The shallow warm and less saline water in summer and fall was in probability generated by both heating and freshwater supply in the bay as well as lateral transport from outside of the bay.

Fig. 3 shows seasonal variability of the depth of the surface mixed layer in the central part (Stn. S3) of the Sagami Bay. The seasonal variability of each year from 1999 to 2006 shows that the mixed layer depth (MLD) was deepest in February, shoaled rapidly in March and April, became shallowest in summer months (June to August), and then gradually deepened from September to February (Fig. 3A). The deepest MLD in February, varied from year to year, ranging from 115 m in 2003 to 160 m in 2004 (Figs. 3A-C). On the basis of the seasonal variability of the averaged MLD (Fig. 3B), each year can be classified into four seasons with regard to seasonal evolution of the MLD as depicted in Fig. 3C; (a) winter (December to February) when the MLD became deeper due to intensive cooling, (b) spring (March to May) when the MLD became shallower due to heating, (c) summer (June to August) when the MLD were very shallow and closed to the surface, and (d) fall (September to November) when the MLD started to deepen due to gradual cooling. As is evident from Fig. 2, the deeper water (σ_θ>26) in Sagami Bay showed little variability in the T-S diagram. The depth corresponding to 26 σ_θ was ca. 130-160 m in Sagami Bay at Stn. S3 with little seasonal variability (Fig. 3C). Based on the seasonal variability of the ML and the depth of $\sigma_\theta = 26$, we classified the upper 200 m water column of the Sagami Bay into 3 layers; (1) the mixed layer (ML) above the MLD, (2) the intermediate layer (IML) below the MLD and above the depth of σ_θ = 26, and (3) the deeper layer (DL) with σ_θ> 26.

3.2 Development of Nitrate Algorithms

Of the 262 profiles available from the dataset used in this study, 104 profiles were taken in summer and the rest during the other seasons. Also of the 262 profiles, 45 profiles were from Stn. S3. The number of profiles was smallest in winter with 29 profiles (10.9 % data points) of which more than 2/3 (20 profiles) were from Stn. S3. In spring and fall there were 50 profiles (17.5% data points) and 79 profiles (20.7% data points), respectively. The seasonal unevenness in the number of profiles apparently resulted from the observations out of the Stn.S3 during R/V Tansei Maru cruises in summer and fall. Number of profiles at Stn. S3 showed less seasonal bias. As for the spatial distribution of the data set, almost half of the data were obtained at Stn. S3 (~45.1%), but other 9 stations distributed evenly in the bay (Fig. 1B). The frequency distribution of data numbers in 3 different waters classified in section 3.1 shows

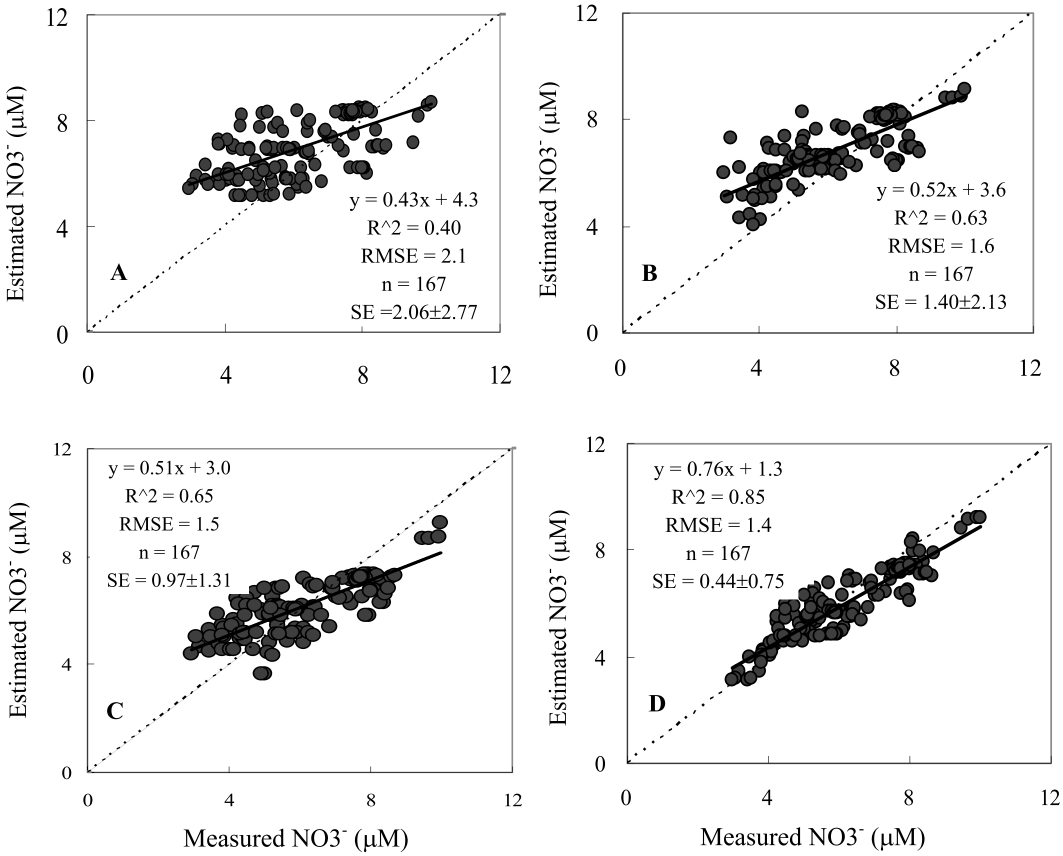

Fig. 4. Relationship between measured and estimated nitrate concentrations in ML as an example of processes in developing the nitrate algorithms: (A) Linear regression with temperature, (B) Multiple linear regression with temperature and Chl *a*, (C) Multiple linear regression with Log T and Chl *a*, and (D) Multiple linear regression with temperature, Log T and Chl *a*. RMSE and SE indicate Root Mean Square Error and Standard Error with the standard deviation, respectively.

about 57.2% (1903 points) of data points were obtained from the IML, with highest number of 1183 points found in summer. On the other hand, data from ML and DL consisted of 22.8% and 20%, respectively. This vertical distribution showed that the database was more concentrated at IML than other waters.

Table 3 shows the correlations between measured nitrate concentration and each possible predictor variable in different water masses and seasons. For the most cases within the ML and the IML, temperature, the logarithm of temperature (Log T), and Chl *a* correlated significantly with nitrate. In contrast, high correlation was observed for the DL nitrate with temperature and salinity. The large difference in temperature within the water column, between the surface ML and DL, required the conversion of temperature to Log T to reduce the variability in GOES *et al.* (1999; 2000), SILIÓ-CALZADA *et al.* (2008) and STEINHOFF *et al.* (2009) independently showed that the addition of the Log T improved NO_3^- prediction by multiple-linear regression.

An example of the improved relationship between nitrate concentration in the ML and its predictor variables with additional variable is shown in Fig. 4. Addition of Chl *a* and the use of Log T both improved the predictability of the model compared to the regression with temperature alone (Figs. 4A and 4B). Furthermore, the combination of temperature, Chl *a*

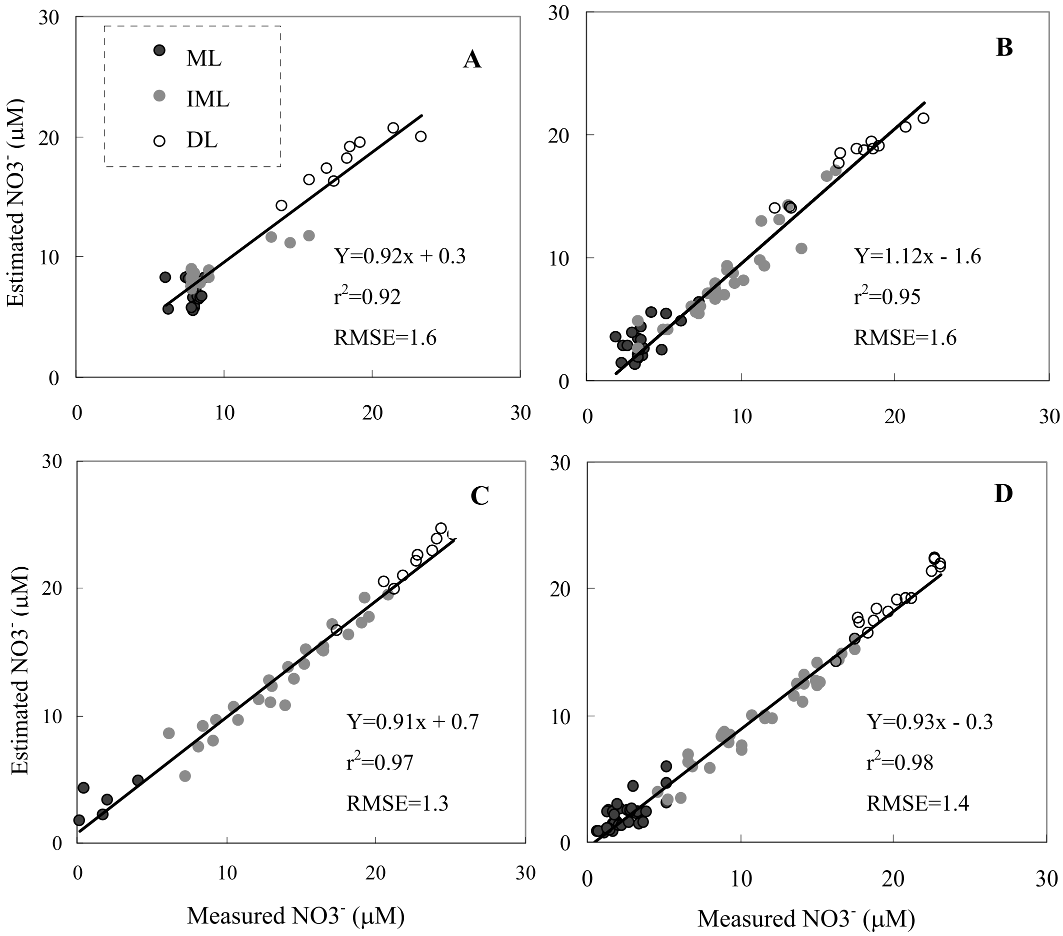

Fig. 5. Regressions of measured and estimated nitrate concentrations using independent data sets obtained in Sagami Bay from locations shown in Figure 1B in winter (A), spring (B), summer (C) and fall (D).

and Log T significantly improved the predictability (Figs. 4C and 4D). Hereafter, we used multiple-linear regression analysis of nitrate with temperature, Log T and Chl *a* for the ML and the IML season by season, and for DL with temperature, Log T and salinity.

Nitrate concentration in each season was estimated by applying the above algorithms to ML and IML (Eq. 2) and DL (Eq. 3), respectively.

$$\text{Nitrate } [\mu M] = a + b\ T\ [\text{deg C}] + c\ \text{Chl } a\ [\mu g\ l^{-1}] + e\ \log T\ [\text{deg C}] \quad (2)$$

$$\text{Nitrate } [\mu M] = a + b\ T\ [\text{deg C}] + d\ \text{Sal}\ [\text{psu}] + e\ \log T [\text{deg C}] \quad (3)$$

Results of multiple-linear regression to estimate nitrate concentration are shown in Table 4. The r^2 ranged from 0.59 to 0.93, and RMSE from 0.6 to 2.1 μM. It is notable that the lowest r^2 of 0.59 and the second smallest RMSE of 0.7 μM were observed in the summer ML, where the data number was smallest and the nitrate concentration was the lowest. Except for the summer, r^2 values during the other seasons were larger than 0.73.

3.3. Applicability of the Regression Models

A set of independent data (Table 2) from several stations obtained during the *R/V* Tansei Maru cruises (Fig. 1B) was used to test the performance of the nitrate algorithms. The

NO_3^- profiles in the upper 200 m water column of the Sagami Bay were computed by using a combination of multiple-regression models for the three layers described in the previous section, and the correlations between measured and estimated nitrate are shown in Fig. 5. The highest performance of the algorithms was observed in fall with r^2 and RMSE of 0.98 and 1.4 μM, respectively. On the other hand, the lowest performance was found during winter with r^2 and RMSE of 0.92 and 1.6 μM, respectively. In spring and summer the algorithm results in r^2 and RMSE of 0.95 and 1.6 μM, 0.97 and 1.3 μM, respectively.

4. Discussion

4.1. Water Mass and Nitrate Variability in Sagami Bay

Our analysis of T-S diagrams (Fig. 2) revealed conspicuous seasonal variations of water mass. The largest variability in the T-S diagram was observed during summer and fall in the surface mixed layer. This high temperature and less saline water mass appeared on the top of the winter low temperature and high saline water mass. The water mass with density of σ_θ >24.3, and more specifically σ_θ >26, showed very stable T-S signatures for all seasons during the 10 years. This may suggest that this water mass came from same source during all seasons. This water mass was at surface in winter and spring and below the surface water in summer and fall.

The high temperature and less saline surface water appeared in summer to fall and showed large variability in their T-S signatures. Like any other temperate region, radiation flux increases during summer and peaks in July (HASHIMOTO *et al.*, 2005; 2006; ISHIZAKA *et al.*, 2007), and high heat flux in summer affects the heat content in the upper water column of the Sagami Bay and changes the water properties (OTOBE and ASAI, 1985). Freshwater input from river and lateral transport of less saline water from Tokyo Bay can also influence the surface water of Sagami Bay, specifically during summer (KANDA *et al.*, 2003; YANAGI and HINATA, 2004). The variability of T-S diagram at the surface indicated the heterogeneity of the less saline water in summer. Those dynamics of the water mass in the Sagami Bay was fairly consistent with the one described previously (IWATA, 1985) and similar to the near-by Suruga Bay (NAKAMURA, 1982 referred in IWATA *et al.*, 2005).

It is known that the vertical mixing and the upward transport of nutrients in Sagami Bay during the summer stratified season takes place due to physical forcing, such as regional upwelling (KAMATANI *et al.*, 1981), topographic effect on strong current (TAKAHASHI *et al.*, 1980), and wind (ATKINSON *et al.*, 1982). In most cases, these vertical mixing and upwelling events cause relaxation of the seasonal thermocline resulting in mixing in the upper water column < ~100m and/or upwelling of deeper water to the upper water. These events may be responsible for the large variability of surface T-S diagram during the summer and fall.

Previous studies (BAEK *et al.*, 2009; TAKAHASHI *et al.*, 1986) have shown that riverine inputs and mixing/upwelling can lead to significant increases in the amount of nitrate in the bay. However, in our dataset, nitrate concentrations in the surface mixed layer in summer were usually low (0.1–1.6 μM), despite indications of large riverine inputs and upwelling as evident from the variability at the surface in the T-S diagram during summer. One possibility is that nitrate increases due to these sporadic events was quickly consumed by phytoplankton and depleted. On the basis of experimental data and field-observations, ISHIZAKA *et al.* (1983) and TAKAHASHI *et al.* (1986) showed that excess nitrate present in upwelling water in the Sagami Bay was rapidly depleted by fast growing phytoplankton to limiting concentrations. Satellite data showing large heterogeneity of Chl *a* and primary production in the bay provides an indication of the rapid response of phytoplankton to these events and the variability in nitrate associated with phytoplankton biomass distribution (ISHIZAKA *et al.*, 1992; 2007; KANDA *et al.*, 2003). These observations justify the importance of inclusion of Chl *a* in the nitrate algorithm.

The lack of seasonal variability in the T-S diagram (Fig. 2) for waters below the depth of

$\sigma_\theta = 26$, between 130 and 160 m, suggested minimal influence of lateral advection on nitrate distribution. Furthermore, it suggested that the DL was stable in the entire region of the Sagami Bay at least during the observation period. This was an unexpected finding because the Sagami Bay is located close to the Kuroshio and hence its water mass structure is believed to be affected by its dynamical forcing (YANAGI and HINATA, 2004; HINATA *et al.*, 2005). It has also been reported that the Oyashio water sometimes intrudes into Sagami Bay in much deeper layer (~300m; SENJYU *et al,* 1998). Since our observations were limited to 200m, we do not know much about the depth range of the stable water mass below this depth.

Nitrate concentration in the DL were strongly correlated with temperature and salinity but not with Chl *a*. This is not an unexpected finding as phytoplankton photosynthetic activity and nutrient uptake in deeper waters would have been minimal as is also evident from the extremely low Chl *a* concentration in the DL (<0.07 $\mu g\ l^{-1}$) compared to the ML (0.03–7.12 $\mu g\ l^{-1}$) and the IML (0.01–4.16 $\mu g\ l^{-1}$).

In the present study, we defined the IML as the water mass below the ML and above the DL. It was very thin during winter/spring and thick during summer/fall because of the deep and shallow ML, respectively. The T-S diagrams (Figs. 2B-C) show that the ranges of σ_θ in IML were narrower, 25.6–26 and 25.3–26, in winter and spring and but were broader, 23.1–26 and 23.6–26, in summer and fall, respectively. This broader range in σ_θ, in the IML, can be attributed to mixing of the warm and less saline summer-time surface water with waters in the upper part of the IML. The large amount of phytoplankton in the upper part of IML, which was invariably shallower than the euphotic zone (~30–67 m, HASHIMOTO *et al.*, 2006) during summer, justified the inclusion of Chl *a* as a predictor variable in the multiple-linear regression of nitrate concentration in the IML.

4.2. Nitrate Algorithm: Strength and Limitations

Our data set revealed that nitrate concentration could be estimated with a great degree of reliability using temperature and Chl *a* in the ML as well as in the IML. In the DL, nitrate correlated well with temperature and salinity (Table 3). This is an important finding not only for explaining what regulates NO_3 variability in the bay, but also for explaining the rationale in our choice of variables for the algorithms for different depths.

There have been previous attempts to estimate nitrate from the temperature, salinity and Chl *a*. GOES *et al.* (1999; 2000) and SILIÓ-CALZADA *et al.* (2008) showed that variability of nitrate at the surface could be explained by SST and Chl *a* in the Pacific Ocean and in the Benguela Upwelling, respectively. GARSIDE and GARSIDE (1995) and GARSIDE *et al.* (1996) were able to explain the variability of nitrate and its origin on the basis of temperature for deep water in the Equatorial Pacific and coastal water of the Gulf of Maine and salinity, respectively. IWATA *et al.* (2005) used salinity alone for estimating subsurface nutrient in Suruga Bay, Japan.

In this study, nitrate profile from surface to 200m could be estimated using different algorithms for different layers of vertical structure taking into account not only different physical and biological processes but the origins and mixing of different source waters. The estimation of accurate vertical profile of nitrate was not possible by other methods, and the present algorithms should be helpful for understanding the biogeochemical processes in dynamical marine environments such as the Sagami Bay.

In general, the algorithms performed better in the IML and in the DL than in the ML (Table 4). One of the reasons for this discrepancy may be the highly dynamic nature of the ML with large variability in temperature, salinity, and Chl *a*, but a small range of variability in nitrate, particularly during summer. In the ML, the weakest correlations between measured and estimated nitrate were found in summer. This is perhaps due to the low nitrate concentrations observed, but also because of the large variability of temperature as

Table 4. Results of multiple linear regressions for estimating nitrate concentration. N is number of data. The values of a, b, c, d and e are constant and coefficients of equation for mixed layer water and intermediate water (eq. 2) and for deeper water (eq.3)

No Seasons	Constant	T	Chl a	Sal	Log T	R^2	RMSE (μM)	N
	a	b	c	d	e			
Mixed Layer								
1 Winter	145.57	3.27**	3.41**	----	-68.32*	0.73	1.4	212
2 Spring	95.51	0.85**	1.81**	----	-93.44*	0.78	1.9	215
3 Summer	212.7	0.85*	0.30*	----	-37.08*	0.59	0.7	87
4 Fall	22.12	-1.51**	2.41**	----	3.58**	0.92	1.2	242
Intermediate Layer								
5 Winter	329.52	11.5**	-5.92**	----	-181.02**	0.76	2.1	222
6 Spring	187.85	3.68**	-1.77*	----	-86.59**	0.83	1.8	255
7 Summer	83.88	-0.15**	-0.12*	----	-25.76**	0.93	0.6	1183
8 Fall	98.76	0.92**	-3.72**	----	-36.71**	0.88	1.8	243
Deeper Layer								
9 All Seasons	416.33	2.01**	---	11.00**	2.01**	0.90	0.6	665

** $P<0.001$; * $P<0.05$

compared to other seasons.

For the development of the algorithms, almost half (∼45%) of the nitrate profiles came from Stn. S3. The use of data from a single station could bias the algorithms. However, our tests of validity of the algorithms with independent data from wider locations showed good performance (Fig. 5). The comparison between *in situ* and estimated nitrate profiles in different seasons (Figs. 6A-D) clearly showed the seasonal variation of nitrate profile particularly in ML and IML as a result of seasonal evolution of the MLD, with maximum and minimum in winter and summer, respectively. In winter, the decreasing SST causes deepening of MLD and results in highest and homogeneous nitrate throughout the ML (Fig. 6A). On the other hand, during summer, the sea surface heating in combination with phytoplankton productivity prevailing physical mixing results in very shallow MLD with lower nitrate (Fig. 6C) compared to spring (Fig. 6B) and fall (Fig. 6D).

Since the algorithms of this study had been developed based on general water mass characteristics within the upper 200m of the Sagami Bay, it may be difficult to apply the algorithm when the water is affected by un-identified water masses of different nitrate concentrations, especially in the near-shore stations. Even with this limitation, the fact that DL in ∼130-200m depth of Sagami Bay showed stable T-S-nitrate relationship made us confidence that our algorithms can provide valid estimates of nitrate input from deeper layer coused by wind-induced upwelling and/or topographic effect on Kuroshio current.

We are not certain whether our approach could be directly applicable to other embayments, nevertheless this study suggests that a similar approach could be applicable to reconstruct high resolution nitrate profiles that could be used for studying daily, seasonal to annual changes based on temperature, Chl *a* and salinity from automated instruments commonly used on various oceanographic monitoring platforms, such as floats, gliders and buoys.

5. Conclusions

Algorithms for nitrate, constructed using physical (temperature, salinity) and biological (Chl *a*) data from different water masses in different seasons, were able to yield highly reliable, high-resolution profiles of nitrate in upper 200 m water column of the Sagami Bay. The water mass analysis using T-S diagram and MLD as a criteria to distinguish between water masses, yielded a better basis and understanding of the controlling factors of nitrate

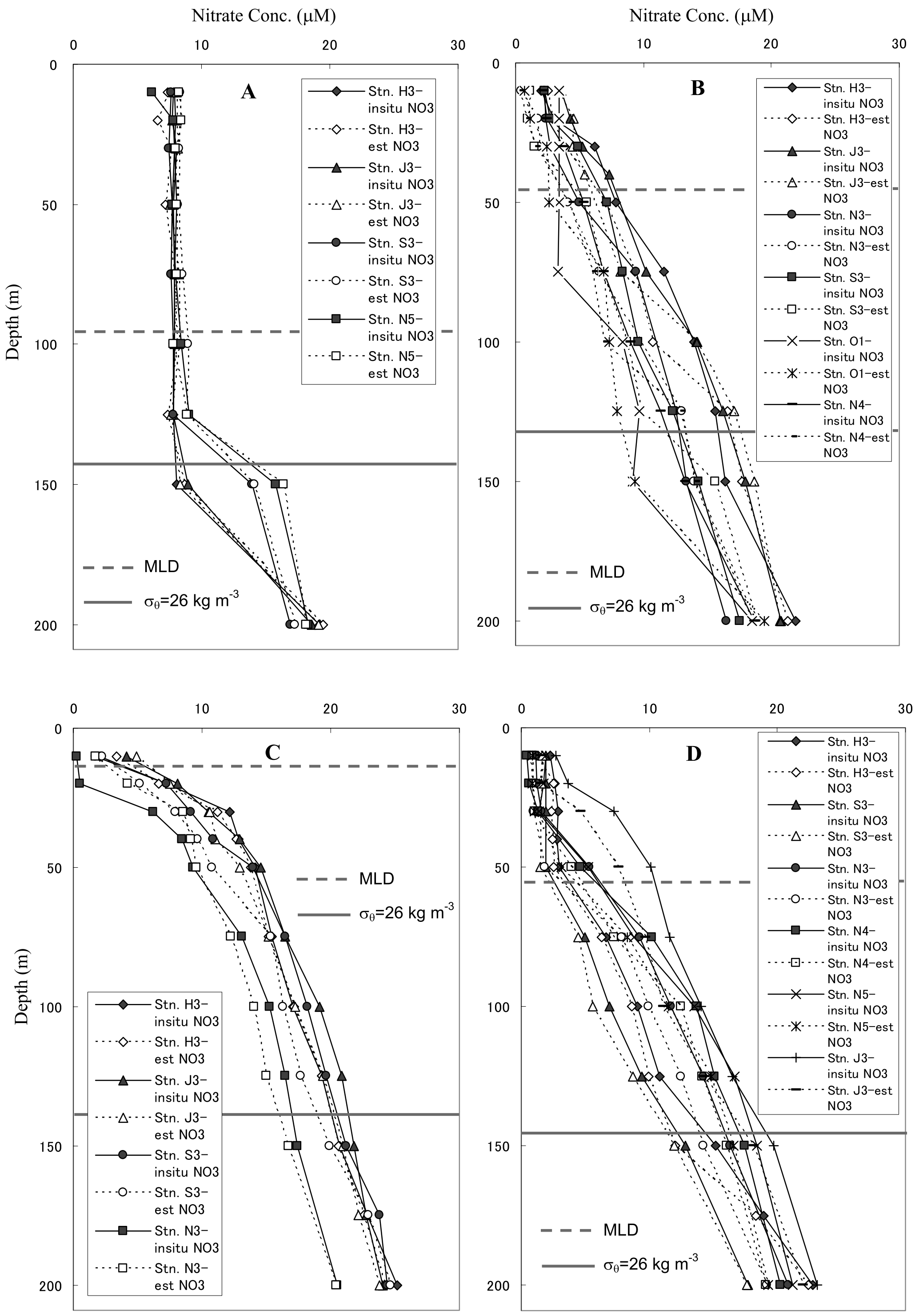

Fig. 6. Comparisons of measured and estimated nitrate profiles in Sagami Bay in winter (A), spring (B), summer (C) and fall (D).

variability in the bay. The analysis helped isolate ML from the DL which had distinct water properties (low temperature, high salinity and nitrate) compared to the IML or the ML.

Previous studies have demonstrated the possibility of nitrate estimation in the MLD derived from temperature (KAMYKOWSKI, 1987; GARSIDE and GARSIDE, 1995; CHAVEZ *et al.*, 1996; SWITZER *et al.*, 2003; HENSON *et al.*, 2003; SHERLOCK *et al.*, 2007). It may be noted that deriving nitrate based on temperature alone is limited because of the highly variable nature of nitrate over space and time (GOES *et al.*, 1999; 2000). Our study suggests that nitrate algorithms based on temperature, salinity and Chl *a* which take into account the water mass characteristics of a given area could be a better and a more robust approach estimating nitrate concentrations in water column even in highly dynamic coastal environments.

This study also demonstrates that these algorithms could be reliably used to fill in the gaps of in situ measurements of nitrate concentration, such data are difficult to obtain by conventional means, such as from research vessels, or another platform, for instance: floats, gliders, and buoys. This study is the first effort to demonstrate the advantages of utilizing a combination of biological and physical parameters for obtaining high resolution nitrate, profiles which could be important for better understanding of carbon fluxes and biogeochemical processes in coastal-oceanic waters.

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根室市三里浜沖海況の季節変化　II. 塩分・密度構造

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Seasonal Variations of the oceanic condition off Sanrihama Beach, Nemuro II. salinity and density structure

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Abstract : The Nemuro City Fisheries Research Institute installed bottom temperature sensors off Sanri-hama Beach, Nemuro in in order to know seasonal variations of environmental circumstance of Hanasaki crabs. 8 stations were set along a straight line extended towards offshore. The depths of stations are 5m through 60m. The observations were made from December 28, 2005 through May 13, 2009. In the previous paper (Nagase *et al.*, 2010) showed that temperature and salinity profiles have usually vertically homogeneous both in summer and in winter seasons. The temperature decreases from shore to offshore in summer season, and it increases in winter season. These trends appear to extend into temperature structure in the East Hokkaido Coastal Current (the Coastal Oyashio in winter season and the East Hokkaido Warm Current in winter season). By using the results of STD observation which were obtained 17 times during the observation. In contrast to temperature gradients, salinity gradients in the nearshore region are opposite to those inside the East Hokkaido Coastal Current: salinity increases toward offshore in summer season, and it decreases in winter season. This would be explained by supply of fresh land water was brought from offshore into the region in summer season. In winter season, the fresher Oyashio Water, originated from the sea area off the Kruil Islands, would be brought into the nearshore region from offshore.We examined the seasonal variation of water type of the 50m depth at the most offshore observation station St. 8, and compared with that of the East Hokkaido Coastal Current Water. The water is almost identical to that in the East Hokkaido Coastal Current Water at 50m depth, but some tendency that the phase of the seasonal variation in nearshore region advances to that of the he East Hokkaido Coastal Current Water

Keywords: *Sanrihama Beach, Nemuro City: STD observation, Seasonal variation of salinity and density fields, The East Hokkaido Coastal Current*

1.　はじめに

根室市水産研究所では、ハナサキガニの成体やその幼生の生活環境を把握するため、根室市太平洋岸、落石半島西の三里浜にある試験操業地に、水深 5m から 60m に至る 8 点の測点を設けて、2005 年 12 月 28 日から 2009 年 5 月 13 日の間、周年にわたる底層水温の観測を行った。また、各測点において、この期間中に 17 回にわたって STD を用いた水温・塩分の鉛直分布を測定した。この観測結果をもとにして三里浜沖における水温

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Nemuro City Fisheries Research Institute

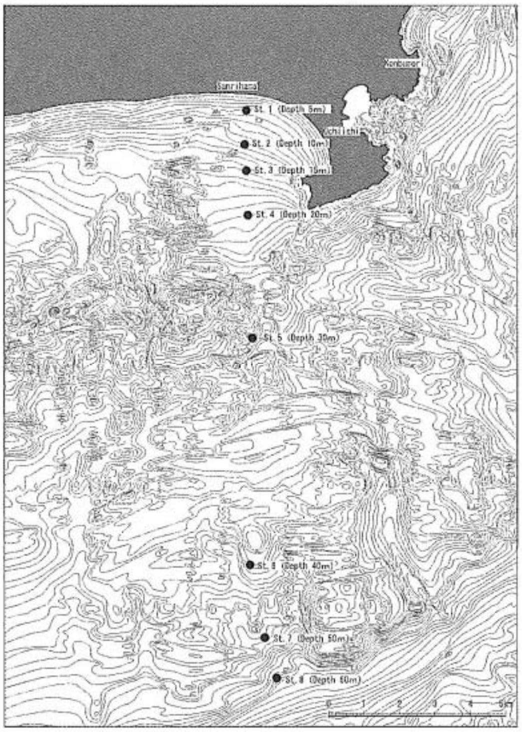

Fig. 1. Positions of 8 STD observation stations off Sanri-hama Beach, Nemuro City. The stations are aligned along a line extending southward. Water depths at stations from St. 1 through St. 8 are 5m, 10m, 15m, 20m, 30m, 40m, 50m, and 60m, respectively. Bottom contours are shown at interval of 1m. The horizontal scale is given at lower right corner.

構造の季節変化特性を調べ、その結果を長瀬ら（2010）が発表した（以後、前論文と呼ぶ）。その結果によると、「夏季」においては、水温は沖方向に移るにしたがって低下し、「冬季」には沖に移るにしたがって上昇する傾向があることが明らかにされた。この傾向は、沖合の道東沿岸流（「夏季」の道東暖流、「冬季」での沿岸親潮）の内部での水温の水平勾配につながっていると考えられる。前論文では塩分構造や密度構造の季節変化についてはほとんど触れなかったが、本論文では、STD 観測の資料をもとにして、塩分・密度場の季節変化を論じる。また、最も沖合の 60m 深の測点（St. 8）の 50m の水温・塩分値を用いて、沖合の道東沿岸流水の水系の季節変化との比較を行う。

2. 観測地点と観測機器

STD 観測の位置（前論文で論じた海底水温の連続測定位置と同じ）と、ハナサキガニ試験操業地付近の水深図を Fig. 1 に示す。観測点は、落石岬西の三里浜から南に延びる線上に配置されている。一番岸よりの水深 5m のところに St. 1 が設けられ、St. 2 以下 St. 8 までの測点は、それぞれ水深 10m、15m、20m、30m、40m、50m、60m のところに設けられている。この海域では西向流が卓越することが知られており、St. 1 から St. 4 までは落石岬による流れの影の部分にあり、前論文で見たように St. 5 より沖の測点とは若干海況特性が異なっている。使用した STD は Alex Electronics Co.製の STD（ATS200-PK）である。STD 観測は、連続海底水温記録の回収、再設置等の作業に際して実施したので、必ずしも規則的に行われていないが、ほぼ周年的な観測を行うことができた。観測は 2007 年 5 月から 2009 年 2 月の間に 17 回行ったが、その実施日を Table 1 に示す。便宜上、観測を実施日の順に、1 から 17 の観測番号を付けている。なお、Table で日付につけた英文字は、水温が沖に向かって低下する傾向を示す「夏季」型を S、水温が沖に向かって上昇する「冬季」型を W で、どちらとも言えない場合を X で示してある（前論文参照）。以下では「夏季」の場合、「冬季」の場合、それ以外の場合の順に、塩分構造と密度構造を見ることにする。

3.「夏季」の塩分・密度構造

水温が沖に向かって低下していく傾向を持つ「夏季」の観測は、観測番号 1〜3 と 8〜13 の 9 回であり、5 月初めから 10 月末までの期間に限られている。この 9 回の観測時の塩分・密度（σ）の鉛直分布を Fig. 2a、b、c に示す。左の欄に塩分分布を、右の欄に密度分布を示す。深さは下向きに 0m から 61m を取っており、塩分については分布形状を見易くするため図毎に目盛を変えている。Fig. 2 については塩分の目盛り線の間隔は 0.2 である。密度については Fig. 2 では横軸は全てに共通に 24.0 から 26.5 までの範囲を取ってあり、目盛り線の間隔は 0.5 である。図には、季節的変化を見易くするため年を無視して日付順に並べてある。測点の区別は、沖合の 4 点は太線で、岸よりの 4 点を細線で示し、それぞれについて、最も沖の点 St. 8、St. 4 を実線で、次の点 St. 7 と St. 3 を点線で、St. 6 と St. 2 を破線で、St. 5 と St. 1 を一点鎖線で示してある。これは前論文での水温分布に用いたものと同様である。水温の鉛直分布については前論文の Fig. 9、Fig. 11、Fig. 12 を参照されたい。

Table 1 Dates of STD observations. Observation date is given in the box corresponding to year column and to month row. Serial observation numbers are given in the column "No.". In the previous paper, we defined "summer state" that temperature tends to decrease from inshore to offshore, and "winter state" that the temperature tends to increase from inshore to offshore. These states are indicated in date column with capitals S (summer state), W (winter state), and X (the others), respectively.

	No.	2007	No.	2008	No.	2009
January			5	30W	16	29X
February					17	26W
Mach						
April			6	3X		
			7	30X		
May	1	29S	8	28S		
June			9	27S		
July	2	28S	10	31S		
August			11	28S		
September			12	26S		
October	3	1S	13	29S		
November			14	26W		
December	4	1W	15	29W		

3-1　塩分構造

前論文（長瀬ら、2010）が示したように、「夏季」においては、水温は表層部分を除けば鉛直方向にほぼ等温であり、その温度は沖に向かうほど低くなる。この沖に向かう水温降下は、必ずしも単調ではなく、何点かがほぼ同じ温度のグループを作ることがあり、時には局所的に測点間で逆転を起こすこともある。Fig. 2 に示された塩分の鉛直分布は、水温の鉛直分布に比べ、ジグザグした短波長の変動がより目立つ。しかし、後で述べる密度の鉛直プロファイルでは短波長の変動は目立たなくなる。これは水温の高い「夏季」では、密度に対する効果が、塩分より水温の方が効いてくることのためであろう。また、「夏季」では表層に水温躍層が発達するが、これに伴って塩分躍層もみられる。この塩分躍層の深さは、一般に水温躍層の深さに比べ、より深くまで達している場合が多い。しかし、塩分躍層より下では、プロファイルに塩分一様層が見られる。水温構造で見たように、塩分一様層の塩分値の沖方向の変化を見ると、「夏季」の分布では一般に沖方向に増大していることが分かる。

塩分構造は、「夏季」期間中にも、顕著な季節的変動を示す。5 月から 6 月にかけては、岸よりの 5 点と沖側の 3 点の分布が、それぞれにグループを形作っており、沖側の方が高塩分になっている。7 月の末ごろの分布は塩分躍層下端の深度が深くなる傾向を示すが、特に 2008 年 7 月 31 日の場合、水温躍層の深さが 10m 程度であるのに対して、沖の St. 7 と St. 8 では、塩分値が深さ 40m に至るまで緩やかに増大している。恐らく、この厚い表層低塩分層は、この時期に道東沖の海域に広く現れる高温・低塩分表層水（永田ら、2009a）の出現に対応するものであろう。しかし、沖合に見られる高温・低塩分表層水は 8〜10 月に最も強勢となるから、沖合よりも先行して現れるようである。8 月末の構造では、緩やかに深度とともに塩分が増大する層はほとんど消滅し、プロファイルが沿直に走る部分が目立つようになる。しかし、沖に向かうほど塩分値が高くなる傾向はやはり明確に認められる。2007 年 10 月 1 日の構造は、2008 年 8 月の構造に似ているが、2008 年 9 月 26 日の構造は各地点とも、等塩分層が発達している。沖に向かう塩分の増大傾向はやはり、認められる。2008 年 10 月 29 日の塩分構造には大きな短波長の振動が見られ、「夏季」の終末期を示しているように思われる。沖への塩分増大傾向は非常に見難くなっているが、全体としてその傾向は保存されている。

このように「夏季」の期間の塩分構造は、季節による若干の相違はあるものの、「夏季」を通して塩分が沖に向かって増大する傾向は明らかに見られる。前論文で、水温の沖方向の低下が沖合の道東暖流の水温の水平勾配につながっていることを述べた。しかし、道東暖流は岸沿いに高温・高塩分の水が存在することから定義付けられているように、その内部では沖向きに塩分が減少している。したがって、三里浜沖と、道東暖流内での塩分の水平勾配の向きが逆になっている。おそらく、極沿岸部では、「夏季」において陸水の影響を強

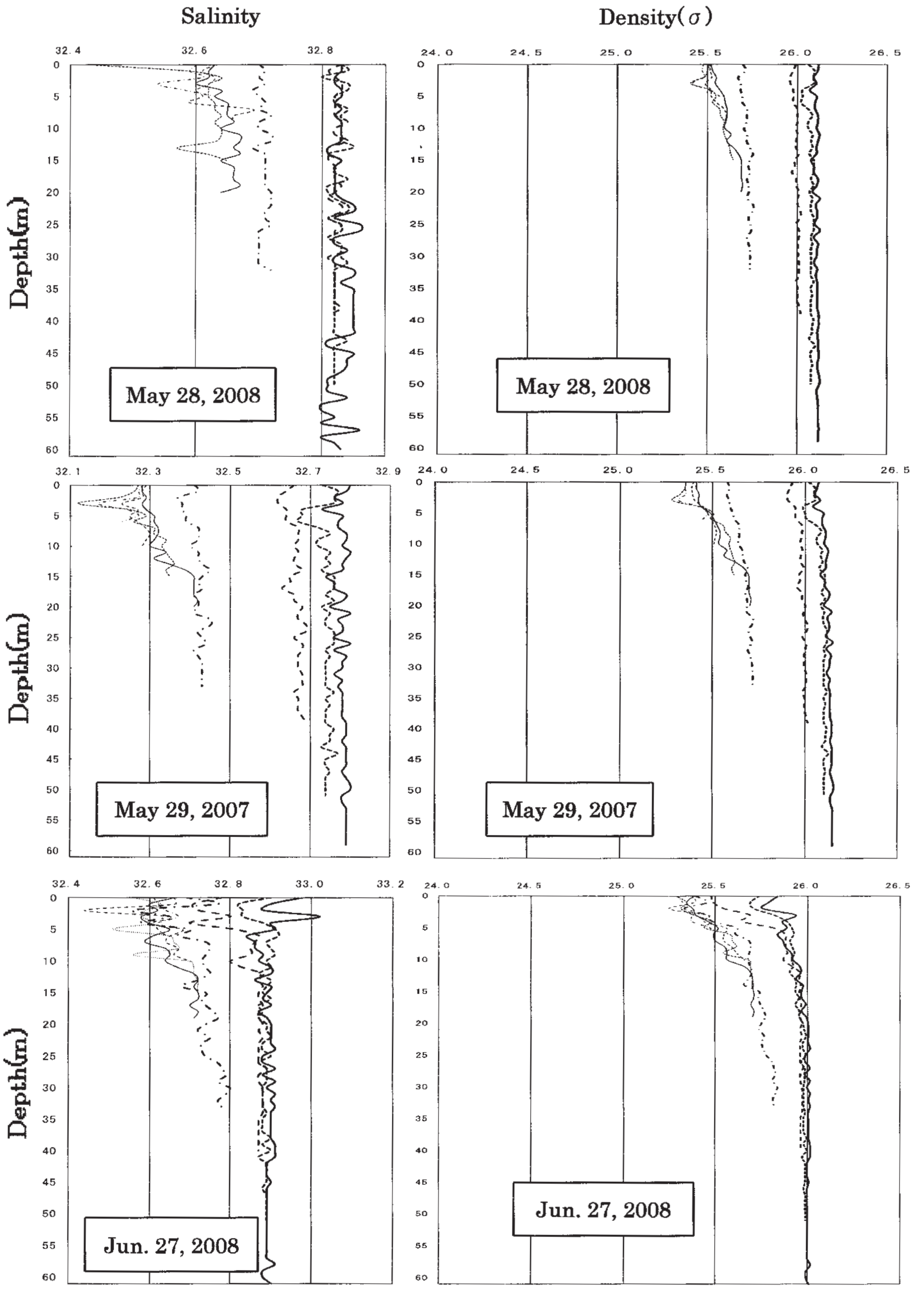

Fig. 2a. Vertical salinity (left column) and density (right column) profiles measured with STD in "summer season" . Thin curves indicate 4 inshore stations (dotted and dashed lines are used for St. 1, dashed lines for St. 2, dotted lines for St. 3 and full lines for St. 4). Thick curves indicate 4 offshore stations (dotted and dashed lines for St. 5, dashed lines for St. 6, dotted lines for St. 7, and full lines for St. 8. Depth range is taken from 0m to 61m, and density range from 24.0 to 26.5. The upper figures show the profiles measured on May 28, 2008 (observation No. 8), and the salinity range is taken from 32.4 to 32.9 in this figure. The middle figures show the profiles measured on May 29, 2007 (observation No. 1), and the salinity range is taken from 32.1to 32.9. The lower figures show the profiles measured on June 27, 2008 (observation No. 9), and the salinity range is taken from 32.4 to 33.2.

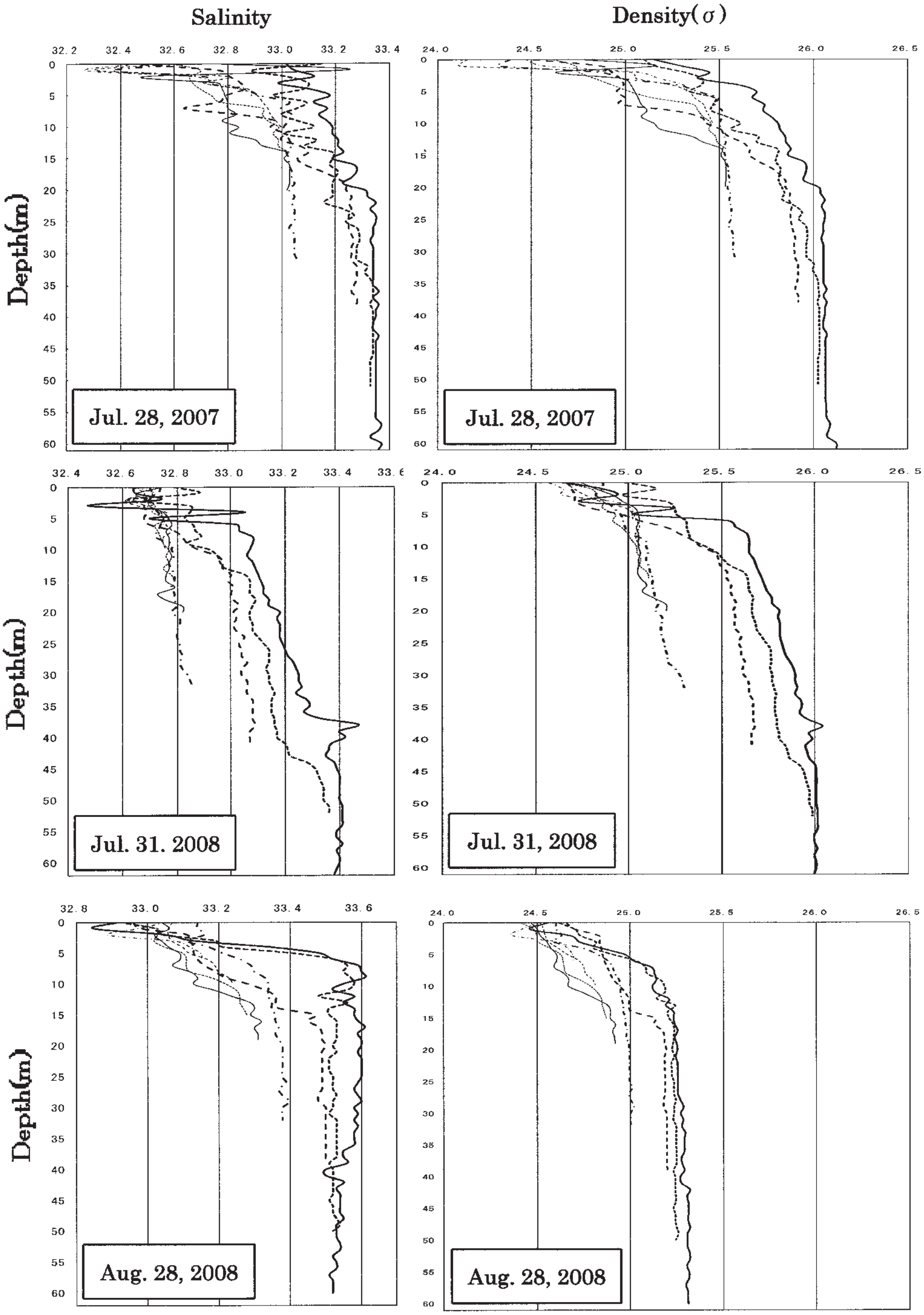

Fig. 2b. Same as in Fig. 2a, except for observation dates. The upper figures show the profiles measured on July 28, 2007 (observation No. 2), and the salinity range is taken from 32.2 to 33.4. The middle figures show the profiles measured on July 31, 2008 (observation No. 10), and the salinity range is taken from 32.4 to 33.6. The lower figures show the profiles measured on August 28, 2008 (observation No. 9), and the salinity range is taken from 32.8 to 33.7.

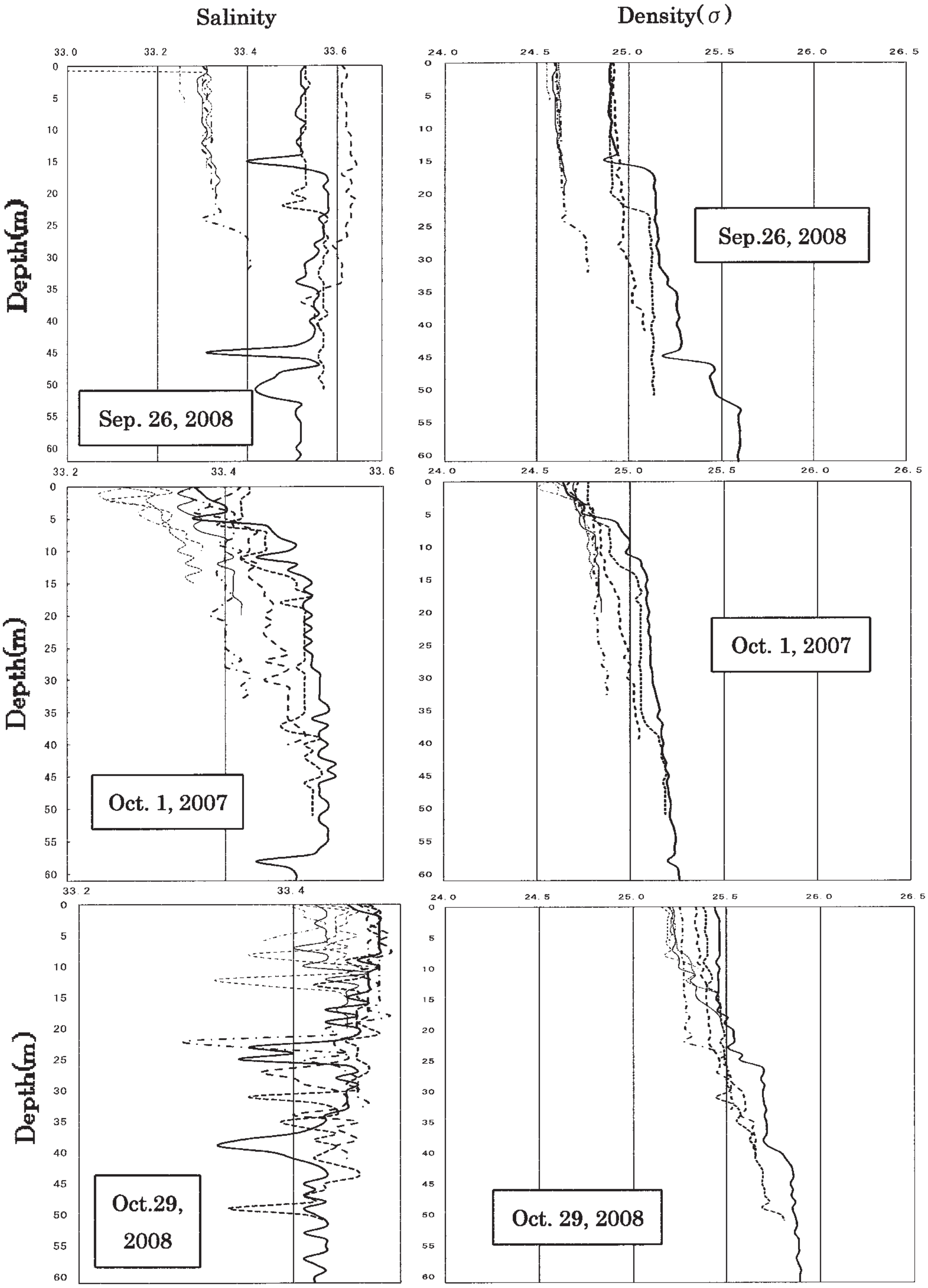

Fig. 2c. Same as in Fig. 2a, except for observation dates. The upper figures show the profiles measured on September 26, 2008 (observation No. 12), and the salinity range is taken from 33.0 to 33.7. The middle figures show the profiles measured on October 1, 2007 (observation No. 3), and the salinity range is taken from 33.2 to 33.6. The lower figures show the profiles measured on October 29, 2008 (observation No. 13), and the salinity range is taken from 33.2 to 33.5.

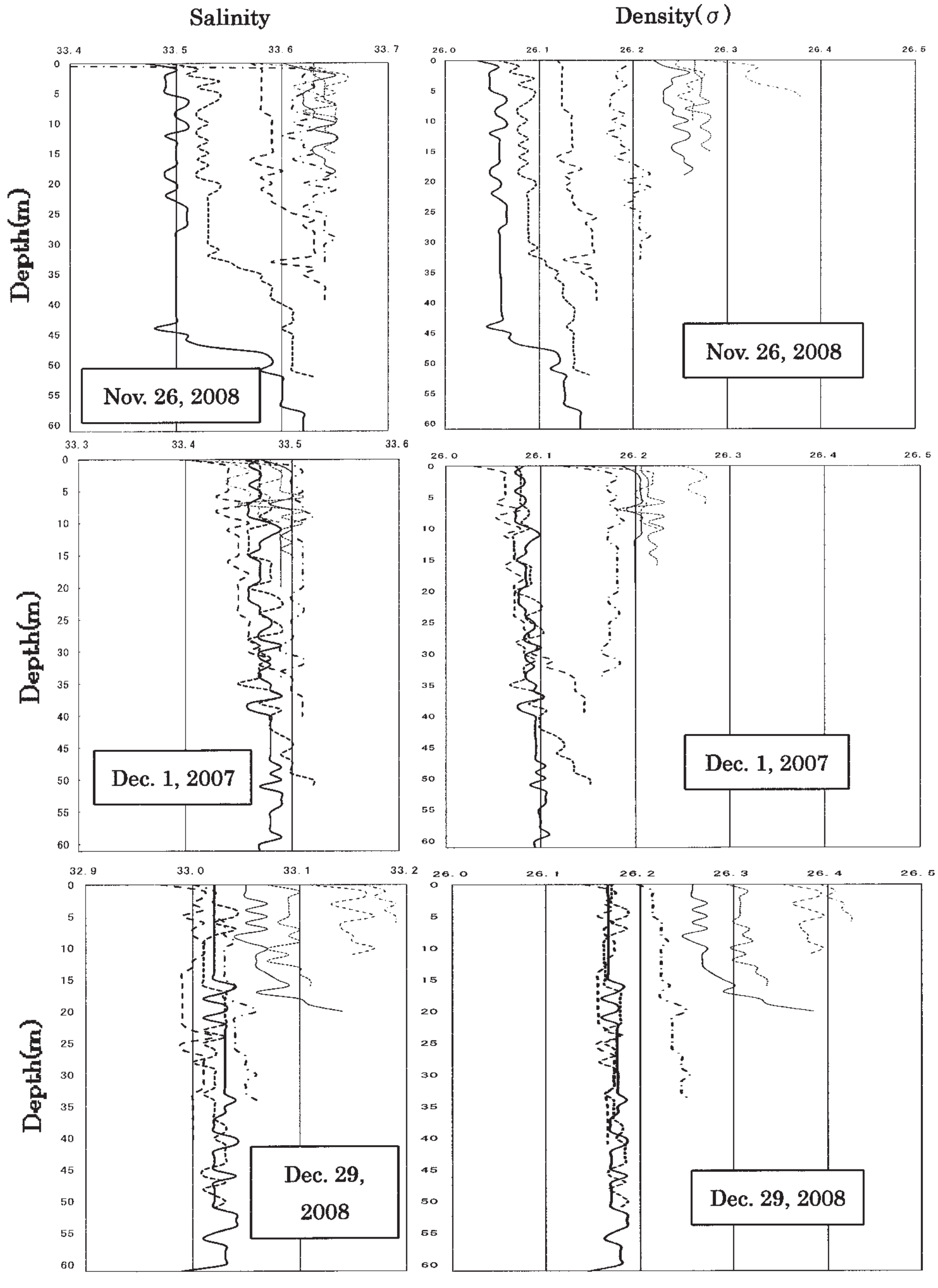

Fig. 3a. Vertical salinity (left column) and density (right column) profiles measured with STD in "winter season". Thin curves indicate 4 inshore stations (dotted and dashed lines are used for St. 1, dashed lines for St. 2, dotted lines for St. 3 and full lines for St. 4). Thick curves indicate 4 offshore stations (dotted and dashed lines for St. 5, dashed lines for St. 6, dotted lines for St. 7, and full lines for St. 8). Depth range is taken from 0m to 61m, and density range from 26.0 to 26.5. The upper figures show the profiles measured on November 26, 2008 (observation No. 14), and the salinity range is taken from 33.4 to 33.7. The middle figures show the profiles measured on December 1, 2007 (observation No. 4), and the salinity range is taken from 33.3 to 33.6. The lower figures show the profiles measured on December 29, 2008 (observation No.15), and the salinity range is taken from 32.9 to 33.2.

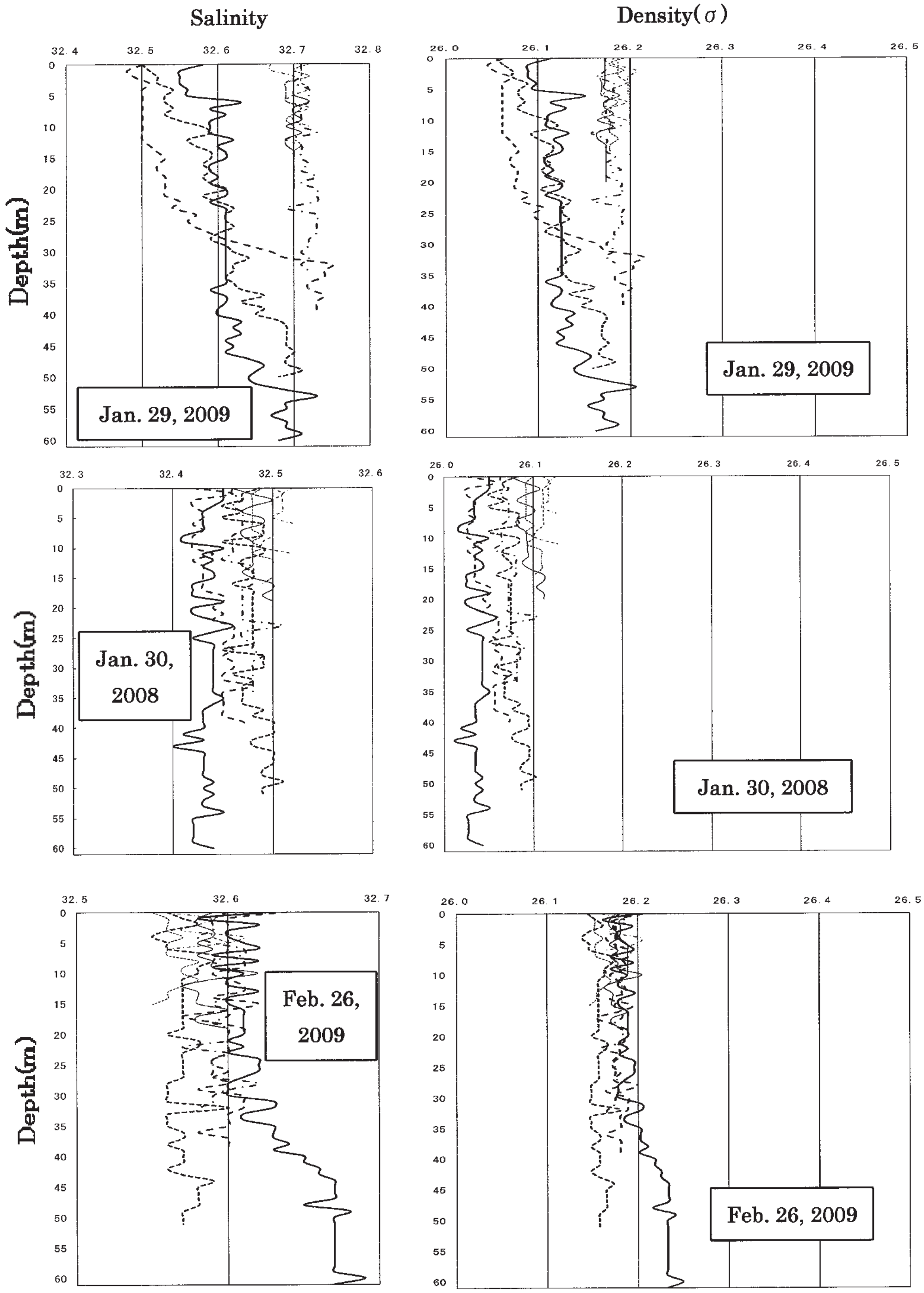

Fig. 3b. Same as in Fig. 3a, except for observation dates. The upper figures show the profiles measured on January 29, 2009 (observation No. 16), and the salinity range is taken from 32.4 to 32.8. The middle figures show the profiles measured on January 30, 2008 (observation No. 10), and the salinity range is taken from 32.3 to 32.6. The lower figures show the profiles measured on February 26, 2009 (observation No.17), and the salinity range is taken from 32.5to 32.7.

く受けていて、塩分が薄められているためであろう。

3-2　密度構造

密度（σ）構造で、先ず気付くのは、塩分構造に見られるような、プロファイルに現れる短波長のジグザク形状が弱められ、場合によってはほとんど姿を消すことである。このことは、短波長のジグザク形状について、水温・塩分のそれぞれの密度に対する効果が打ち消し合っている場合もあるようであるが、水温の高い「夏季」では、密度が塩分よりも水温構造により支配されているためと考えられる。しかし、短波長成分を除くと、密度構造は、一般に水温構造よりも塩分構造によりよく似ている。亜寒帯海域の海では、水温よりも塩分の方がより密度の決定要因となっていることがここにも現れている。

5月から9月に至る期間の塩分・密度の両プロファイルを見ると、岸側の5点と沖側の3点のそれぞれが、グループを作っているように見える。卓越する西向流の落石半島の陰にある岸側4点と、かなり沖にあるSt. 5が、このように長期にわたって同じような性質を持つ原因は分からない。この時期、落石岬より東方のこの時期の卓越流が等深線に沿う形で西向きというよりは南西方向に流れていて、St. 5が落石岬の陰になる状態が続いていたのかもしれない。

塩分構造が複雑な形になっている2008年10月29日は「夏季」の終末期にあたるかも知れない。しかし、密度構造を見ると明らかに沖向きに増大している。後で述べるように、「冬季」の三里浜沖での密度は沖向きに減少する傾向を示すから、10月29日は「夏季」の様相を示していたと言える。

4.「冬季」の塩分・密度構造

水温が沖に向かって上昇していく傾向を持つ「冬季」の観測は、観測番号4と14〜15および17の4回であり、11月から2月までの期間に限られている。2009年1月の状況は前論文で論じたようにかなり特殊であるが、1月は通常は「冬季」であるので比較のため、この節で論じることにする。「冬季」の観測は、2009年1月のものを含めて6回ある。これらの塩分・密度の鉛直分布をFig. 3aとFig. 3bに示す。プロットの仕方は「夏季」の場合と同じであるが、示されている塩分の範囲は狭くなっており、それに応じて塩分の目盛り線は0.1間隔に引いてある。密度（σ）範囲も26.0〜26.5であり、「夏季」のFig. 2の場合に比べると5倍に拡大している。図の配列は、年を無視して、11月を最初に日付順に並べてある。

2008年11月26日の構造（Fig. 3a上段）は「冬季」の典型的なものと考えられる。塩分は沖に向かって減少する傾向を示し、密度では単調に沖に向かって減少している。2007年12月1日に取られたプロファイル（Fig. 3a中段）では、塩分の沖向きの減少は明確ではないが、岸側の5測点（St. 1〜St. 5）の塩分は、沖側の3測点（St. 6〜St. 8）の塩分より高い。この岸側の測点と沖側の測点の塩分の違いは、密度により明確に現れており、岸側の5測点の密度は沖側の3測点に比べ明確に高く、岸側の5測点については岸に近づくに従って単調に密度が増大している。2008年12月29日の密度構造（Fig. 3a下段）は、2007年12月1日の密度構造によく似ており、似た構造が塩分についても現れている。このような塩分・密度が沖に向かって減少していく傾向は、2008年1月30日の構造（Fig. 3b中段）では若干弱まっているものの、明らかに認められる。この「冬季」においても、水温（前論文）や塩分のプロファイルよりも、密度のプロファイルの方が短波長の波動が目立たなくなっている。

2009年1月29日と2009年2月9日の水温構造は前論文に論じたように典型的な「冬季」の構造特性を示しているとは言えない。2月9日については水温分布（前論文Fig. 12下段右）で見る限り「冬季」の特性を示しているが、1月29日の水温構造（前論文Fig. 12下段中央）は「冬季」の特性と「夏季」の特性が入り混じって現れている。Fig. 3bの塩分・密度構造では、逆に1月29日（Fig. 3b上段）ではほぼ「冬季」の特性が現れているが、2月9日の構造（Fig. 3b下段）では「冬季」の特性が見られない。明確な結論を得るには観測例が少なすぎるが、2008年1月30日の構造においても、「冬季」の特性が11〜12月の観測例（Fig. 3a）に比べて弱まっていることから考えて、沿岸域では1月以降には「冬季」が終末期に入ることを示唆しているように思われる。1月〜2月は沿岸親潮の最盛期であるから、これが事実であるならば、沿岸域の海象が沖合の海象に約3か月先行するという前論文の結論を支持するものである。

このように、水温が沖に向かって上昇する傾向を持つ「冬季」においては、塩分は沖に向かって減少し、密度も沖に向かって減少する傾向があることが示された。

5. 沖合の道東沿岸流域の構造との関係

永田ら（2009a、2009b）は、沖合を流れる道東沿岸流が、年の前半には岸に沿って低温・低塩分の水からなる沿岸親潮として存在し、年の後半

Table 2 Comparison of horizontal temperature, salinity and density（σ）between in the East Hokkaido Coastal Current zone and in the sea off Sanri-hama Beach. “increase” or “decrease” shows trend towards offshore. The attached symbols＋ and ? indicate sense to increase and to decrease density, respectively.

“summer”	temperature	decrease＋	East Hokkaido Warm Current	temperature	decrease＋
	salinity	increase＋		salinity	decrease－
	density	increase＋		density	increase＋
“winter”	temperature	increase－	Coastal Oyashio	temperature	increase－
	salinity	decrease－		salinity	increase＋
	density	decrease－		density	increase＋

には岸に沿って高温・高塩分の水からなる道東暖流として存在することを示している。彼らの求めた水塊構造の季節変化によると、沿岸親潮の場合には密度構造は主として塩分構造によって決まり、道東暖流の場合には水温構造によって決まり、共に密度は沖合に向かって増大する。日下ら（2009）の繋留測流観測の結果では、一年を通して道東沿岸流の流れは岸沿いに南西に流れていることが示されていて、道東沿岸流は地衡流的なバランスを伴う流れであることが分かる。

前節で得られた三里浜沖沿岸域での水温・塩分・密度の沖向きの勾配と、道東沿岸流域のそれぞれの勾配とを比較したのが Table 2 である。この表で、勾配については沖向きに増大（increase）するか、減少（decrease）するかを示しおり、+、－の符号は密度の勾配への寄与の方向性を示している。水温の特性を中心に論じた前論文においては、水温の水平勾配の向きが両海域で一致することから、三里浜沖と道東沿岸流との連続性に注目した。しかし、塩分・密度の水平勾配に関しては連続性は認めることは出来ない。

三里浜沖と道東海流域の主要な違いは、塩分の水平勾配の向きが反対であることである。「夏季」の沿岸域では岸近傍では陸水の流入の影響のため岸近くの海水の塩分が薄められるため沖方向に塩分が増大すると考えるのが自然であろう。一方、「冬季」では、岸近くの海水の塩分が沖側より高くなっている。永田ら（2009a、2009b）は、沿岸親潮の起源の水が、根室水道や国後・択捉島の東方の三角水域を通って供給されることはありえないことを示唆している。そうであるならば、沿岸親潮の低塩分水は、クリル列島の東側を通って供給されるはずである。三里浜沖のような極沿岸海域に注目するならば、低塩分水は沖から供給されることになるために、沖側の塩分が薄くなっていると考えられることになる。このことは、2007年 12 月 1 日の密度構造（Fig. 3 中段右）、2008年 12 月 29 日の塩分・密度構造（Fig. 3a 下段）において、沖向きの高塩分化、沖向き低密度化が、主として沿岸の 4 測点で顕著に見られることからも類推される。現在利用出来る資料は極めて限られているため、明確な結論を出すことは難しいが、今後道東沿岸流の水の起源を求め研究において、ここに述べた仮説は十分考慮されるべきであると考える。

6. 2008 年 4 月における塩分・密度構造

前論文で論じたように 2008 年 3 月初めに大量の流氷が根室水道を通って太平洋に流出し、釧路周辺の海岸に大量の海氷が漂着した。三里浜でも 3 月 3 日に回遊してきた流氷によって St. 5〜St. 8 の 4 測点の底層水温計測システムが流失した。その復旧作業が 4 月 3 日に行われたが、その際に実施した STD 観測の結果水温プロファイルに、水深 30m 付近に非常にシャープな水温躍層が観測された（前論文 Fig. 11 上段左）。この躍層が最も発達していた St. 7 では、31m 深で水温が 0.08℃（塩分 32.25）であったものが、32m 深では水温－0.11℃（塩分 32.41）になっていた。この躍層より上部の水は、その低塩分性から大量に流出してきた流氷の溶融水であると推定された。ただし、この水の水温は躍層より下の水よりは水温は高く、この時期の流氷の溶融水ではそれほど低温な水は作り出せないと考えられる。なお、4 月 30 日に次の STD 観測が行われているが、この時には、躍層は十数 m の厚さを持ち、緩やかな形になっていた。しかし、躍層の水温の値は 1.0〜2.6℃と著しく上昇しており（前論文の Fig. 11 上段中）、4 月初めの躍層がこの時まで維持されていたかの判断は留保されている。

この 4 月 3 日（上）と 4 月 30 日（下）に観測された塩分（左）と密度構造（右）を、Fig. 4 に示す。4 月 3 日には塩分、密度のプロファイルに明確なステップ構造が現れており、低塩分・低密度の流氷溶融水と考えられる水に表層が覆われている。また、4 月 30 日には、ステップ構造がならされて、緩やかな勾配に置き換えられているが、4 月 3 日のステップ構造の名残が認められる。水温構造の場合と異なり、勾配の大きな部分の塩分・密度の値が、やや範囲を広げているものの、4 月

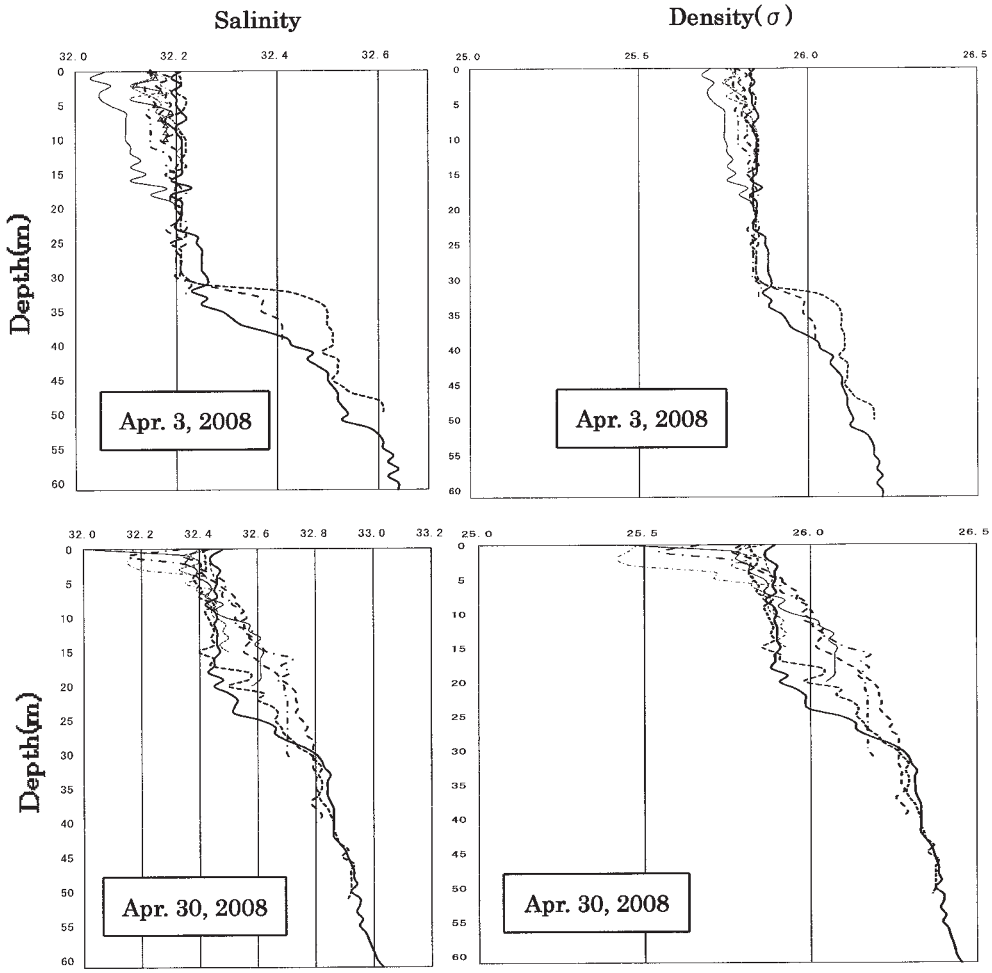

Fig. 4. Same as in Fig. 2a, except for the observations conducted in April, 2008. The density range is taken from 25.0 to 26.5. The upper figures show the profiles measured on April 3, 2008 (observation No. 6), and the salinity range is taken from 32.2 to 33.4. The middle figures show the profiles measured on April 30, 2008 (observation No. 6), and the salinity range is taken from 32.4 to 33.6. The lower figures show the profiles measured on August 28, 2008 (observation No. 7), and the salinity range is taken from 32.0 to 33.2

3日の値とほぼ同じ値に保たれている。表層の水温が4月の昇温期に上昇しても、塩分が保持されていると考えれば、流氷溶融水が4月末まで存在したことになる。水温の低い時期には、海水の密度は主として塩分に寄って決まるという亜寒帯域の特徴がここにも現れている。

7. 三里浜沖の水塊特性の季節変化

永田ら（2009a）は、道東沿岸流の水塊特性の季節変化を論ずるには、50m層の水温・塩分に注目するのが、最適であることを示し、この結果を利用して永田ら（2009b）は道東沿岸流の水塊の季節変化を論じた。三里浜の観測点の沖合のSt. 7とSt. 8でのSTD観測は50m深ないしはそれ以上まで実施されている。その、50m深の資料を用いて、道東沿岸流の水塊特性と比較してみよう。

永田ら（2009b）によると、道東沿岸流の水塊特性は大きな季節変化を示す。各月におけるTS図上での水型の分布範囲は、水温・塩分の双方の断面図に岸沿いに道東暖流あるいは沿岸親潮の構造が現れる場合（ケース1）と、いずれか片方の断面に現れる場合（ケース2）、両者ともに現れない場合（ケース3）とで互いに重なっており、違いはそれほど目立たない。もちろん道東沿岸流が明確に現れる場合の方が、道東暖流の場合には

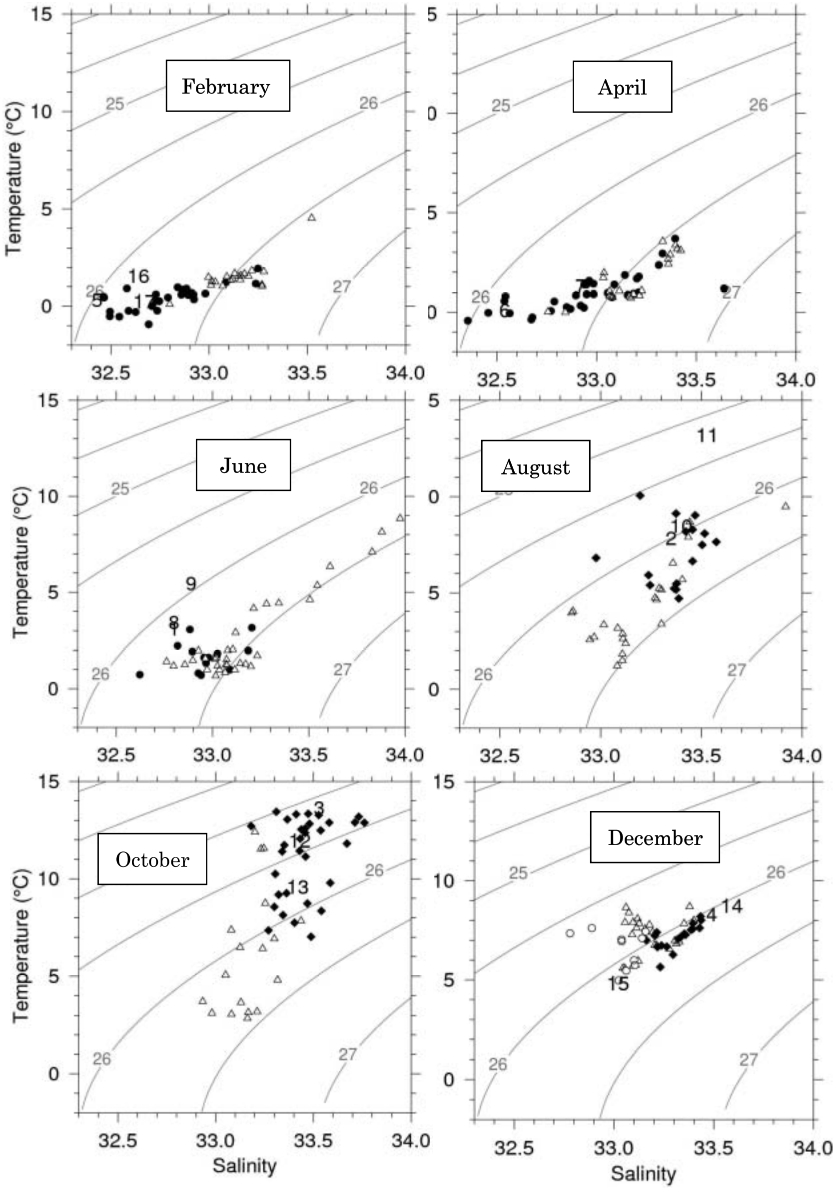

Fig. 5. Scatter diagrams of water types on TS surface of the East Hokkaido Coastal Current Water (Nagata et al., 2009b) and of the water at 50m depth at St. 8. Solid circles (●) indicate the case (1) when cold and fresh water belt (the Coastal Oyashio) can be seen along coast on both of temperature and salinity cross-sections, and open triangles (△) the case (3) when these water belt cannot seen on both of cross-sections for the period of the Coastal Oyashio (February, April and June). Solid diamonds (◆) indicate the case (1) when warm and saline water belt (the East Hokkaio Warm Current) can be seen along coast on both of temperature and salinity cross-sections, and open triangles (△) the case (3) when these water belt cannot seen on both of cross-sections for the period of the East Hokkaido Warm Current (August, October and December). In December, fresh water belt can be sometimes seen, water types of such water is shown with open circle (○) in scatter diagram of December. Water types of the water at 50m depth at St. 8 are shown with numerals. Number indicates the observation number shown in Table 1. Nagata et al. (2009b) used bimonthly data obtained the Hokkaido Nemuro by Fisheries Experiment Station. The data at St. 8 are plotted in figure of the nearest month if they are not observed in February, April, June, August, October or December.

比較的高温・高塩分側に分布し、沿岸親潮が現れる場合の方が比較的低温・低塩分側に分布する。その結果を Fig. 5 にまとめて示すが、ケース 1 を黒丸または黒四角で示して、ケース 3 を白三角で示してある。12 月については、時として沿岸親潮に似た断面が（特に塩分断面に）現れるが、その水型を白丸で示してある。Fig. 5 には、STD 観測で得られた St. 8 の 50m 深の水型を合わせてプロットしてある。50m 深の資料は、St. 7 においても得られているが、St. 8 の値とほとんど同じであるので、St. 8 の資料のみを示す。St. 8 の 50m 深の水型は数字で示してあるが、この数字は Table 1 に示した観測番号を表している。各数字の中央の点が水型のデータ点である。全般的に見て、St. 8 の 50m 深の水の水型は、道東沿岸流の水型の分布域、それも水温・塩分の断面分布両方に構造の現れるケース 1 の分布域の中か、その近傍に現れており、道東沿岸流とほぼ同じ水型の水であることが分かる。

以下、各月の分布特性について若干の考察を行って見よう。

（1）2 月の所にプロットした観測番号 16 と 17 は、いずれも 2009 年に取られたものである。前論文で指摘したように 2009 年の「冬季」は、他の年に比べて、やや異なった様相を示しているが、少なくとも St. 8 の 50m 深の水の水型に関しては、沿岸親潮の水型と同じである。

（2）4 月の観測番号 6 と 7 の水型は、沿岸親潮の水型と一致する。この時流氷溶融水と思われる低塩分水が 30m 以浅の表層に認められているが（前論文 6 章)、50m 層はステップ構造より十分深く、沖合の沿岸親潮の水型と同じ性質を持つことは自然である。溶融水が周辺の沿岸親潮水とかなり違った性質を持っていたことが分かるが、このことは少なくとも 3～4 月には溶融水がそれほど冷たい水を作りえないことを示している。

（3）6 月の図にプロットした観測番号 9 の水型、8 月にプロッロした観測番号 11 の水型は、道東沿岸流の水型の分布域からかなり外れている。しかし、6 月～8 月、あるいは 8 月～10 月の間で、道東沿岸流の水型の範囲が大きく変化している。もし、三里浜海域の現象が、沖合より約 3 ヶ月先行しているという前論文の結論を考慮すれば、これらのデータは、それぞれ 8 月あるいは 10 月にプロットするべきかもすれない。そうすれば、これらの水型は道東沿岸流の水型の分布域の中に含まれることになる。

（4）12 月は道東暖流の季節と考えられるが、断面には沿岸親潮に似た構造が現れることがある。St. 8 の 50m 深の水の水型が、道東暖流の水型の直線状の分布域の低塩分側あるいは高塩分側の延長線上に現れるのは興味深い。限られた資料から何らかの結論を得ることはできないが、今後検討すべき事柄である。

8. おわりに

前論文（長瀬ら、2010）では、底層水温の連続測定の結果と 17 回の STD の観測の結果から、三里浜沖の水温構造の季節変化特性を論じた。この論文では、STD 観測資料から、塩分および密度構造の季節変化を検討し、前論文で得られた結論の補強ないしは再検討を行ったものである。前論文では、水温の沖向きの変化は、沖合の道東沿岸流の内部構造にそのまま繋がって行くことを強調したが、塩分の沖向きの変化は、沖合とは逆向きになっていることが示された。しかし、この現象は、道東暖流の時期である「夏季」においては陸水の流入のために、岸近くでは塩分が低下しており、沿岸親潮の時期である「冬季」では、親潮水が根室水道や三角領域から供給されるのではなく、クリル列島の東岸沖からの供給であることから、むしろ沖側で低塩分化が起こっていると解釈することが出来る。この論文では、また、一番沖の St. 8 の 50m 深の水の水型の季節変化を道東沿岸流水の水型のそれとの比較を行った。若干の岸側の位相の先行現象を考慮すれば、St. 8 の 50m 深の水の水型は、明確な断面構造をともなった場合の道東沿岸流の水型にほぼ一致する。

その他の点では、本論文での結論は、前論文の結論を補強する形になっている。ただ、水温や塩分の鉛直プロファイルに現れる短波長の振動が、密度の鉛直プロファイルがよりスムーズになり、季節変化がより見易くなっている。STD 観測は 17 回しか行えなかったが、将来の観測では、塩分の連続観測や、より頻繁な STD ないしは CTD による観測が望まれる。また、現在、利用できる測流資料が非常に少ない。ADCP 等による直接測流資料の収集が緊急の課題である。なお、本研究は、根室市水産研究所とロシアのサフニロ（SakhNIRO）研究所との共同研究ハナサキ・プロジェクトの一環として実施されたものである。

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資　料

第48巻第2号掲載欧文論文の和文要旨

小野　敦史*，石丸　隆，田中　祐志：2003，2005 年夏季の南大洋インド洋セクターにおけるサルパ類の分布と個体群構造

南大洋生態系の底辺を支える動物群のひとつであるサルパ類の分布と個体群構造を深度別に調べるために，2003，2005年夏季に南大洋アデリーランド沖において，網口面積8 m^2プランクトンネット（RMT 8 ネット）による最大2886 mまでの層別定量採集を行った．2種類のサルパ類，*Salpa thompsoni*と*Ihlea racovitzai*が確認され，前者が優占した。*S. thompsoni*では未成熟連鎖個体と成熟単独個体が表層に出現したのに対し，成熟連鎖個体と未成熟単独個体は深層に多かった。このことは，*S. thompsoni*が発育に伴い鉛直移動することを示唆する。また，成熟連鎖個体も単独個体も65°20′S以南では殆ど出現しなかったことから，65°20′Sより南側に出現した*S. thompsoni*個体群は再生産していなかったと考えられる。

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Andreas A. Hutahaean[1,6]，石坂　丞二[2*]，森本　昭彦[2]，神田　穣太[3]，堀本　奈穂[3]，才野　敏郎[4,5]：相模湾の上層の季節的な硝酸塩プロファイルの推定アルゴリズム

水温，塩分，クロロフィル *a*（Chl *a*）などの海洋データを用いて，相模湾の上層の硝酸塩プロファイルを推定する方法を提唱した。1999年6月から2008年11月までの10年間のデータセットの解析で，相模湾の上層200 mの硝酸塩のプロファイルはそこでの季節的な変動によることが明らかとなった。上層200 mは，表層混合層，中層，深層の3つの層に分けることができた。表層混合層は季節的な変動が大きかった。一方，深度130-160 mに分布するσ_θ＝26以深の深層では季節変動が少なかった。表層混合層と中層上部の水は，夏と秋に暖かく低塩分だったため，季節的な加熱と淡水流入に影響され，さらにその大きな変動はその水の空間的な不均一性を表すと考えられた。硝酸塩とその予測変数の季節的な変動を考慮し，上部の二層の硝酸塩濃度はそれぞれの季節ごとに水温とChl *a*で表すことができた。深層の硝酸塩は季節的に分けず水温と塩分で説明できた。三層の硝酸塩の経験的アルゴリズムで，相模湾の四季の硝酸塩プロファイルを推定した。アルゴリズムのパフォーマンスを独立のデータセットで評価したところ，各季節の硝酸塩の測定値と推定値の決定係数と二乗平均平方根差は，それぞれ0.92～0.98 と 1.3～1.6 μMであった。

われわれの知識では，これは沿岸域の上層200 mにおける硝酸塩プロファイルを，水温，塩分，Chl *a*データで再現した初めての研究である。このようなデータベースは現在，船，フロート，グライダー，ブイなど様々なプラットフォーム上のCTDとChl *a*センサーで測定されるため，このようなアルゴリズムは非常に変動の激しい沿岸域のような海洋環境の生物地球化学循環の研究を助けるだろう。

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Société franco-japonaise d'océanographie, Tokyo

学　会　記　事

1. 2010年９月22日（金）に東京海洋大学９−203会議室において2010年度第２回幹事会が開催された。

審議事項：

（１）　前回の議事録にそって、Techno-Ocean 2010 準備の進捗状況を確認した。

１）Techno-Ocean 2010 Special Sessionのプログラム（案）およびスケジュール案の確認。

２）50周年記念式典の進行係は森永副会長に決定した。

３）第10回TPPC（９月13日）の報告（河野）
Proceeding paperは９月22日に締め切り。VIPレセプション参加者、祝辞のお願いの確認。

４）フランス国旗の掲揚が提案され、小松副会長がシンポジウム事務局に確認することとした。

５）名誉会員および元会長への招待状を発送することとした（荒川が担当）。

６）笹川日仏財団からの寄付が決定したことが報告された。

７）テクノオーシャンのその他の行事予定連絡。10月14日８時30分：テープカット（今脇会長、エノック氏）。10月15日：バンケット挨拶（今脇会長）。

（２）　第14回日仏海洋学シンポジウム第２部の予定確認

１）10月19日午前10時、日仏会館１階ホールでシンポジウム第２部を開催。その予定とプログラム案を確認した。

２）９時30分〜10時、同ホールで日仏、仏日両学会の事前打ち合わせ。

３）12時〜13時30分　日仏会館館長との昼食会（小池幹事が担当）。

（３）　評議員会および総会について

１）評議員会はメール会議とする。議案を確認し、３号議案の文言と４号議案の資料を修正した。

２）総会は、10月19日14時〜、日仏会館５階501会議室で行なうこととし、そのスケジュールを確認した。15時から学会賞記念講演会、17時から懇親会を予定。

（４）　50周年記念誌の編集について
記念誌の内容は、「50年の歩み」とシンポジウムの論文とする。フランス側発表者への投稿依頼を吉田編集委員長が作成する。掲載料無料、原稿は刷り上り４ページとすることを決めた。この印刷費について、寄付を含めて今後検討することとした。

（５）　その他

１）従来、連絡先として使用していた日仏会館フランス事務所の電話番号は今後使用しないこととした。学会封筒やホームページの連絡先電話番号として、"03-5463-0467" を使用する。

２）学会ホームページはいままで国立情報学研究所のサーバで運用されていたが、このサービスが23年度末に停止することになった。今後の運用について、内田幹事が検討することとした。

2. 新入会員

氏名	所属
Girault Mathias（学生会員）	東京海洋大学 〒108-8477 東京都港区港南4-5-7
林　美鶴（正会員）	神戸大学 〒658-0022 兵庫県神戸市東灘区深江南町5-1-1

3. 退会
小島　博

4. 住所変更
長谷川英一　水産工学研究所
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高橋　暁　独立法人産業技術総合研究所
〒739-0046 広島県東広島市鏡山3-11-32

5. 寄贈図書および資料
農工研ニュース（農村工学研究所）；No.66, 67, 68, 69
神奈川県立博物館研究報告；平成21年度版
神奈川県立博物館研究報告；39号
FRAN　NEWS；22, 23
水産総合研究センター　研究報告；29, 30
広島観光コンベンション；Vol.78-80
Ship & Ocean Newsletter；No. 230-244
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水産技術；第２巻２号
ぶらりねっとCHIBA；120
ニュースレター（東京大学海洋研究所）；20
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「海―自然と文化」；Vol.7 No.3, Vol.8 No.1
Techno-ocean News；No.37-39
海洋白書；2010年度
養殖研究レター；6
養殖技術の新たな展開; 21年度版
東海大学海洋研究所研究報告；31号
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（正会員・学生会員）

	年度より入会	年　　月　　日申込
氏　名 ローマ字		年　　月　　日　生
勤務先	住　所　〒 機関名 電　話　　　　E-mail:	
自　宅	住　所　〒 電　話　　　　E-mail:	
紹介会員氏名		
送付金額　　　円	送金方法	
会誌の送り先（希望する方に○をつける）	勤務先　　　自　宅	

（以下は学会事務局用）

受付	名簿原簿	会費原簿	あて名カード	学会記事

入会申込書送付先：〒150-0013 東京都渋谷区恵比寿 3-9-25

（財）日仏会館内

日 仏 海 洋 学 会

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