ی ه U 236 إ چ

U ج گ و

^{236}U ^{236}U ف ٍ

^{236}U نجم Cs 137

ثي

ذ

1.

2011 3 ج ض ° گ

ج ٍ ج ° د

°

^{238}U ض U ف ٍ

4.56×10^{9} ^{238}U ^{234}U 2.45×10^{5}

^{235}U 7.03×10^{8} U ف ٍ

°

ج

ج U يرظم ج بي

U گ

U ج ض

U ض كح

U Pb ض $^{1)}$ U

ف ٍ Th ^{238}U ^{234}U ^{230}Th ^{232}Th $^{2\ 3)}$

طط

^{236}U 2.34×10^{7} ج ف ٍ U گ

^{236}U /

$^{4\ 8)}$ AMS $^{236}U/^{238}U$ 10^{-12} $^{9)}$

^{236}U گ د

گ ^{236}U ں 4 $^{10)}$ ج U گ $^{235}U(n, \gamma)$

$^{238}U(n, 3n)$ ^{236}U گ Mg Na ں گ طط α

(α, n) ٠ گ U گ

گ $^{236}U/^{238}U$ $3\ 10^{-14}$ $7\ 10^{-13}$

AMS چ ض ٠ U ^{235}U

^{236}U ^{236}U ^{235}U $^{235}U(n, \gamma)$

U گ U

گ $^{236}U/^{238}U$ 10^{-7} 10^{-3} یر (4 چ

تص ^{240}Pu $6.35\ 10^{3}$

α ^{236}U ^{240}Pu ^{236}U 2012

$1.0\ 10^{9}$ $5.0\ 10^{11}$ atoms m^{-2} $^{236}U/^{238}U$ $2.6\ 10^{-12}$ $5.3\ 10^{-11}$ گ ^{236}U

ں ^{236}U ^{238}U

گ $^{238}U(n, 3n)$

ں ^{236}U $1.8\ 10^{13}$

atom m^{-2} یر ذ منج 900 kg ^{236}U چ (7 8

گ ^{236}U

گ ^{236}U

2.

چ ں

ج صلعم ف

صي لی چ

ج چ

چ

چ چ ضح

گ

ٰ٠ شي ٰ٠ ضح چ

ج ف چ

لی

س

ظم لی ۔ ٥

کج

1950 ض 1960 ض صلعم ض ض تص

چ ض

^{137}Cs 30.2 765 PBq 10^{15} Bq چ شتي

1963 چ (11 12 ج

ثي ف ^{226}Ra ^{228}Ra منج

ضح گ منج

^{3}H Cs Pu

^{3}H

12.3 ^{3}H 1990

ضح

^{236}U ج چ ف ۔

2009 بجي AK

NG IK HS 4 ۔

4.7 cm 30 cm

Fig. 1 5 cm

=

3.2.2

^{236}U گ 9 cm

Fig. 1

ج 1 cm 5 cm

نی طعم

3.3

3.3.1

= 2 mm

56 mm 39 mm Ge ف ORTEC

GWL 120230 S γ 1

γ MX 033 ن 2000 3 1

12 00 ^{137}Cs 6.27 Bq g^{-1} 40 g Cs 137 661.7 keV

Cs 137 س ۔

U ف ۔ ^{238}U $^{236}U/^{238}U$ گ U ف ۔

α AMS طعم

30 cm ج 30 g 3 450

طعم 15M HNO_3 100 mL 140 5

30 H_2O_2 2 mL 3000 rpm 10 ج

شحي 15M HNO_3 100 mL 140 3 ج غمد

مذب 1 4 15 AMS $^{236}U/^{238}U$ α ^{238}U

ICP MS Pu Pu د

U 238 ^{232}U 2.9806 dpm mL^{-1} 0.1 ml 140

= د ^{232}U ^{233}U گ

^{236}U AMS

گ ^{236}U 15M HNO_3 مذب =

250 mL NH_4OH pH 7 8 U ف ۔ نجم

12M HCl 7M

U = 20 mL 10M HCl

50 mL 10M HCl ۔ Dowex® 1x8 تمس 0.8 m

2M HCl 80 mL U 140 H_2SO_4
15 U NH_4OH pH 4 U 2.5 cm
Si ^{238}U α

U 236/U 238 ^{238}U U 140
20 mL U Fe 1000 mg mL^{-1} 3 mL NH_4OH
50 mL 90 12 800 3
AMS Cs U
^{238}U ^{236}U TOF MS AMS
VERA
Steier [9] Sakaguchi [10] Si ^{238}U AMS
$^{236}U/^{238}U$ ^{236}U

3.3.2

^{137}Cs U
20 L 45 L 15M HNO_3 200 mL 100 mg mL^{-1} ^{133}Cs 2.8 mL
2 AMP
4 g 2 Cs AMP 45 L
$^{236}U/^{238}U$ Pu AMP 80 12 γ
^{137}Cs
AMP Cs ^{137}Cs AMP 0.01 g 0.1% TMAH
ICP MS Re ICP MS Agilent 7700
^{133}Cs Cs ^{137}Cs
AMP $^{236}U/^{238}U$ 100 mg mL^{-1} Fe
2 mL NH_4OH pH 7 8 U U
U
^{238}U ICP MS Agilent 7700 In
ICP MS ^{238}U AMS $^{236}U/^{238}U$ ^{236}U

3.3.3

U 30 mL 15M HNO_3 3 mL 35% H_2O_2
38% HF 70% $HClO_4$ 10 mL 3 mL 1
HF $HClO_4$ 5 10M HCl
10 mL 100 mg mL^{-1} 2 mL $^{236}U/^{238}U$ U
ICP MS ^{238}U
20 L ^{236}U 0 250
m 250 1000 m 1000 2000 m 2000 m bottom

3.3.4

^{137}Cs U
105 24 3 4 g

pH 1 1 L 100 mg mL^{-1} ^{133}Cs 1.4 mL

AMP 2 g Cs

^{236}U/^{238}U Pu AMP 1 cm γ

^{137}Cs

U Pu

4.

4.1 ^{236}U ^{137}Cs

^{236}U ^{137}Cs ^{236}U/^{137}Cs

Table 1 5 cm

^{137}Cs

Table 1 ^{236}U, ^{137}Cs inventories and ^{236}U/^{137}Cs ratio in surface soil.

Sampling	^{236}U	^{137}Cs	^{236}U/^{137}Cs
Station	($\times 10^{13}$ atom m^{-2})	($\times 10^{3}$ Bq m^{-2})	($\times 10^{9}$ atom Bq^{-1})
AK1	1.27 ± 0.10	2.66 ± 0.06	4.78 ± 0.36
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
.34 ± 0.03	4.10 ± 0.12	IK1	1.78 ± 0.0[illegible]
.66 ± 0.02	3.97 ± 0.24	HS1	0.67 ± 0.03

19 20)

^{236}U ^{137}Cs

^{236}U/^{137}Cs (0.59 2.56) 10^{13} atom m^{-2} (1.09 4.34) 10^{3} Bq m^{-2} (3.97 6.61) 10^{9} atom Bq^{-1} Sakaguchi (2009 2010)[7 8)]

^{236}U ^{137}Cs ^{236}U/^{137}Cs 17.8 10^{12} atom m^{-2} 1.89 10^{3} Bq m^{-2} 4.88 10^{9} atom Bq^{-1}

^{236}U ^{137}Cs

4.2 ^{236}U ^{137}Cs

CR58

psu

μmol kg^{-1} σθ

kg m^{-3} Fig. 2

1000 m

1000 m

CR66

CR34

CR58

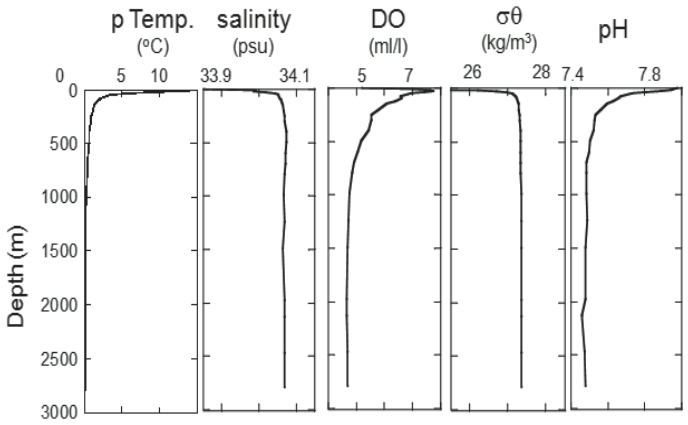


Fig. 2. Depth profiles of potential temperature (°C), salinity (psu), dissolved oxygen (ml/l), potential density (σθ: kg/m^3) and pH (SWS scale 25°C) data at CR58. σθ is the density calculated with *in situ* salinity, potential temperature, and pressure =0 , minus 1000 kg/m^3.

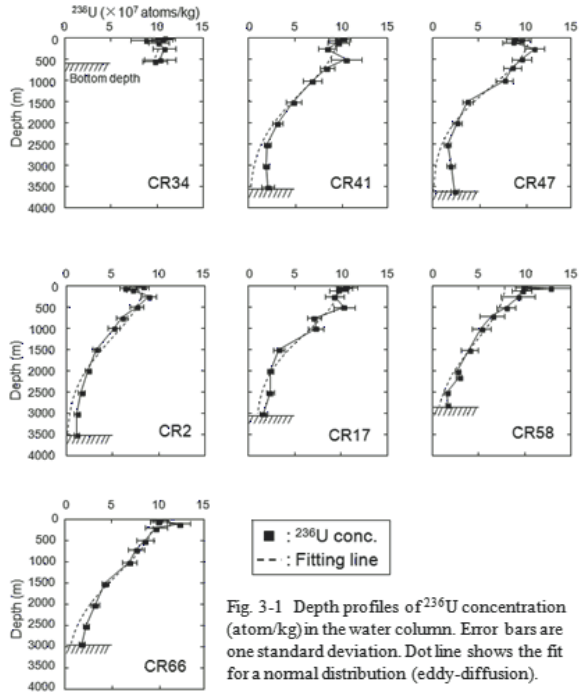
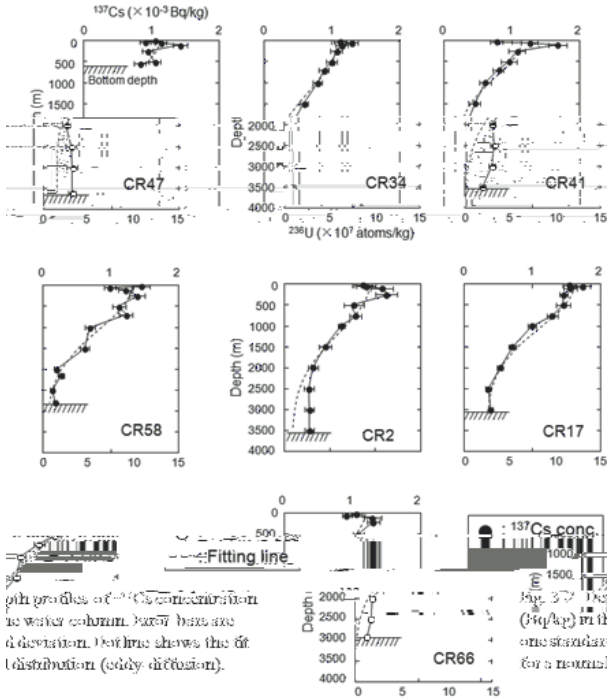


Fig. 3-1 Depth profiles of ^{236}U concentration (atom/kg) in the water column. Error bars are one standard deviation. Dot line shows the fit for a normal distribution (eddy-diffusion).



گ ^{236}U ^{137}Cs نجم Fig. 3-1 3-2

20 L

^{236}U 1

^{236}U سد ير (12.7 1.06) 10^{6} atom kg^{-1}

سد (0.15 0.19) 10^{6} atom kg^{-1}

U ف ^{238}U ج

16 21 27)

گ ^{236}U/^{238}U

سد (0.20 0.24) 10^{-9} تمى

1

گ ^{236}U/^{238}U

ير شي

گ ^{236}U

گ ^{236}U

Table 2 گ ^{236}U

ج ض چ ض

(6.95 3.67) 10^{3} atom kg^{-1}

ير گ ^{236}U

1/10000 1/1000 ^{236}U

گ ^{236}U

1 گ ^{236}U

س AMS ف پ

تمى ض5%

سي نجم

ير ^{236}U

^{236}U

100 500

ج ئهـ بخي

ير سد ير (1.75 1.32) 10^{-9}

د [28]

Table 2 Concentration of ^{236}U in seawater and suspended solid.

	Depth	^{236}U in SW	^{236}U in SS
	(m)	(× 10^{6} atom kg-SW^{-1})	(× 10^{3} atom kg-SW^{-1})
Surface	20-250	9.94 ± 0.23	6.95 ± 6.04
UJSPW	250-1000	9.46 ± 0.26	N.D.
DJSPW	1000-2000	5.63 ± 0.23	3.67 ± 0.97
BJSPW	2000-bottom	2.20 ± 0.08	4.98 ± 1.65

N.D. :Not Detected
UJSPW: Upper Japan Sea Proper Water, DJSPW: Deeper Japan Sea Proper Water
BJSPW: Bottom Japan Sea Proper Water

4.3 ^{236}U ^{137}Cs

گ ^{236}U ^{137}Cs

$^{236}U/^{137}Cs$ Table 3

^{236}U ^{137}Cs

$^{236}U/^{137}Cs$ (0.58 1.63) 10^{13} atom m^{-2} (0.58 2.35) 10^{3} Bq m^{-2} (5.84 9.97) 10^{9} atom Bq^{-1} Table 1

یر

یر گ

^{236}U ضح

^{236}U

Table 3 ^{236}U, ^{137}Cs inventories and $^{236}U/^{137}Cs$ ratio in seawater column.

Sampling	^{236}U	^{137}Cs	$^{236}U/^{137}Cs$
Station	($\times 10^{13}$ atom m^{-2})	($\times 10^{3}$ Bq m^{-2})	($\times 10^{9}$ atom Bq^{-1})
CR2	1.56 ± 0.06	2.17 ± 0.10	7.17 ± 0.46
CR17	1.37 ± 0.06	2.35 ± 0.06	5.84 ± 0.31
CR34	0.58 ± 0.05	0.58 ± 0.03	9.97 ± 0.93
CR41	1.63 ± 0.09	2.05 ± 0.07	7.96 ± 0.50
CR47	1.59 ± 0.07	1.98 ± 0.10	8.05 ± 0.54
CR66	1.44 ± 0.06	1.52 ± 0.06	9.46 ± 0.52
CR58	1.37 ± 0.08	1.40 ± 0.05	9.82 ± 0.71

ں شحي ضح س ج

گ ^{236}U ^{236}U CR34 (0.89 0.03) 10^{11} atom m^{-2} CR41 (1.20 0.06) 10^{11} atom m^{-2}, CR1 (1.40 0.03) 10^{11} atom m^{-2}

^{236}U (0.58 1.63) 10^{13} atom m^{-2} Table 3 1/100

CR14 گ

^{137}Cs 37 Bq m^{-2} Ito et al. [29]

یر

گ ^{137}Cs گ ^{137}Cs 1/40 ^{236}U 2 ج ضشي

Cs د

^{236}U ^{137}Cs گ ء

4.4 ^{236}U

^{236}U ں ضح

^{137}Cs

Cs 137 ^{236}U سد یر 1.67 1.29 mBq kg^{-1} نجم

سي Fig. 3-2 سد یر 0.17 0.33 mBq kg^{-1} تص

[30 31]

^{137}Cs گ چ

[32] ج U-236 ^{137}Cs

ڑ ڑ کج سخ 2σ CR58

50 m 700 m CR47 50 m 100 m R 0.9 ج ض

1963 ضح ضح

ط ^{236}U ^{137}Cs کج یر 4.10 5.56 cm^2 s^{-1} 2.71 5.00 cm^2 s^{-1}

نی س یر یر ^{137}Cs 1 10 cm^2 s^{-1} Tsumune [33]

Ra ف 6 cm^2/s Tanaka [31] یر ^{236}U نی س

ج ض ° ^{236}U

نی گ ^{137}Cs نجم U 236

° 1 L قي نی

د سد

4.5 ^{236}U کا و

° ج

س

34 36)

100 500 16 21 27)

ج 2010 ^{236}U

چ ض

Fig. 1 A B

^{236}U

Fig. 4 CR66

د

ئا

چ ض

40°N 40.5°N

1000 m ض ^{236}U

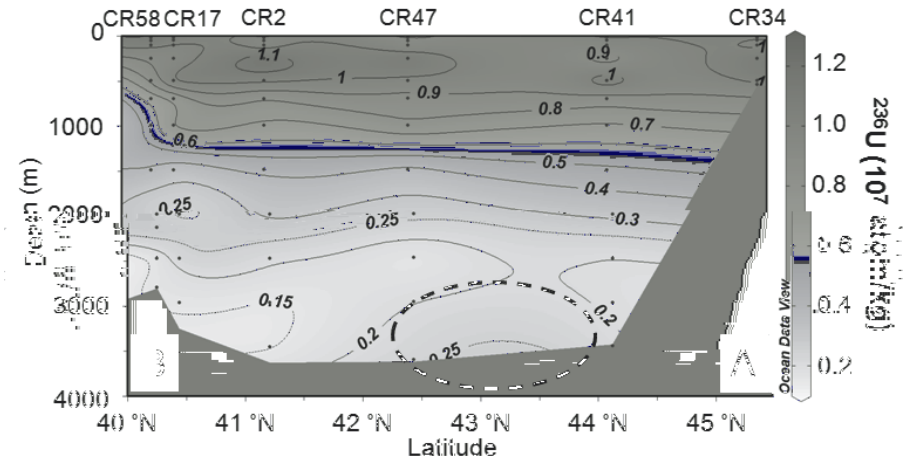


Fig. 4 Contour map of ^{236}U concentration in the Japan Sea through the cross section A to B in the map of Fig. 1. Dashed line circle shows the water mass which has high concentration of ^{236}U.

^{137}Cs

Kumamoto 37) 40°N سد

: :

سد U 236 ^{137}Cs

^{236}U ^{137}Cs ڑ

40°N سد

40.5°N ض 2000 m ^{236}U سي 42°N 44°N

CR41 47 2500 3000 m ض ^{236}U Cs 137

2500 3000 m ض سي

CR41 CR47 ^{236}U ^{137}Cs سي **4.4** کح

Fig. 3 ^{236}U

^{137}Cs

مجد فح شي Senjyu

(2005) 38) بجي

Fig. 5

Aramaki 34)

بجي سي چ

Fig. 5

CR58

CR41 ^{236}U

CR58

^{236}U

^{236}U

40˚N

CR58

Fig. 5

CR58 ^{236}U

KH 10 2

(B) No.

1810018 23710008

1) G. B. Dalrymple: *Special Publications, Geological Society of London* **190 (1)**, 205, (2001).

2) A. Sakaguchi, M. Yamamoto, K. Sasaki, K. Kashiwaya: **35**, 807, (2006).

3) A. Sakaguchi, M. Yamamoto, J. Tomita, K. Mino, K. Sasaki, K. Kashiwaya, T. Kawai: *Quantern. Int.*, **205**, 65 (2009).

4) S. F. Boulyga, S. F. and Heumann, K. G.: *J. Environ. Radioact*. **88**, 1, (2006).

5) S. H. Lee, P. P., Povinec, E.Wyse, M. A. C. Hotchkis: *App. Radiat. Isot.* **66**, 823 (2008).

6) M. Srncik, P. Steier, G. Wallner: *Nucl. Instr. and Meth. B*, **268**, 1146, (2010).

7) A. Sakaguchi, K. Kawai, P. Steier, F. Quinto, K. Mino, J. Tomita, M. Hoshi, N. Whitehead, M. Yamamoto: *Sci. Total Environ.*, **407**, 4238 (2009).

8) A. Sakaguchi, K. Kawai, P. Steier, T. Imanaka, M. Hoshi, S. Endo, K. Zhumadilov, M. Yamamoto: *Sci. Total Environ.* **408**, 5392 (2010).

9) P. Steier, F. Dellinger, O. Forstner, R. Golser, K. Knie, W. Kutschera, A. Priller, F. Quinto, M. Srncik, F. Terrasi, C. Vockenhuber, A. Wallner, G. Wallner, E. M. Wild: *Nucl Instr and Meth B*, **268**, 1045 (2010).

10) A. Sakaguchi, A. Kadokura, P. Steier, Y. Takahashi, K. Shizuma, M. Hoshi, T. Nakakuki, M. Yamamoto: *Earth Planet. Sci. Lett.*, **333**, 165 (2012).

11) Aoyama, M., K. Hirose, Y. Igarashi: *J. Environ. Monitor.* **8**, 431 (2006).

12) Y. Katsuragi: *Pap. Meteorol. Geophys.*, **33**, 277 (1983).

13) M. Uda: *J. imp. Fish. Exp. Sta.*, **5**, 57 (1934) (in Japanese).

14) H. Nitani: "On the deep and the bottom waters in the Japan Sea" p. 151 (1972) (Researches in Hydrography and Oceanography, Hydrographic Department of Japan, Maritime Safety Agency, Tokyo).

15) H. Sudo: *Progr Oceanogr*, **17**, 313 (1986).

16) T. Gamo, Y. Horibe,: *J. Ocealgr. Soci. Japan* **39**, 220 (1983).

17) H. Minami,Y. Kano,K. Ogawa: *J.Oceanogr.* **55**, 197 (1999).

18) K. Kim, k R. Kim, D. H. Min, J. H. Yoon, M. Takematsu: *Geophys. Res. Lett.*, **28**, 3293 (2001).

19) K. Bunzl, H. Forster, W. Kracke, W. Schimmack: *J. Environ. Radioactiv.*, **22**, 11 (1994).

20) M. H. Lee, C. W. Lee: *J. Environ. Radioactiv*. **47**, 253 (2000).

21) M. Christl, J. Lachner, C. Vockenhuber, O. Lechtenfeld, I. Stimac, I., M. R. van der Loeff, H. A. Synal: *Geochim. Cosmochim. Acta.* **77**, 98 (2012).

22) T. Ito, S. Otosaka, H. Kawamura: *J. Nucl. Sci. Technol.* **44**, 912 (2007).

23) T. Ito, T. Aramaki, T. Kitamura, S. Otosaka, T. Suzuki,O, Togawa, T. Kobayashi, T. Senjyu, E. L.

Chaykovskaya, E. V. Karasev, T. S. Lishavskaya, V. P. Novichkov, A. V. Tkalin, A. F. Shcherbinin, Y. N. Volkov: *J. Environ. Radioactiv.* **68**, 249 (2003).

24) K. Tanaka, M. Inoue, J. Misono, K. Komura: *Chikyukagaku*, **40**, 167 (2006) (in Japanese).

25) T. Miyao, K. Hirose, M. Aoyama, Y. Igarashi: *J. Environ. Radioactivity,* **40**, 239 (1998).

26) D. Tsumune, H. Suzuki, T. Saegusa, K. Maruyama, C. Ito, N. Watabe: Central Research Institute of Electric Power Industry U98029, p. 1 (1999) (in Japanese).

27) T. Aramaki, T. Senjyu, O. Togawa, S. Otosaka, T. Suzuki, H. Kitamura, T. Amano, Y. N. Volkov: *Radiocarbon* **49**, 915 (2007).

28) S. Tsunogai, K. Kawada, S. Watanabe, T. Aramaki : *J. Oceanogr.* **59**, 685 (2003).

29) , : نی ج **47**, 32 43.

30) Y. Kumamoto, M. Yoneda, Y. Shibata, H. Kume, A. Tanaka, T. Uehiro, M. Morita: *Geophys. Res. Lett.* **25**, 651 (1998).

31) C. F. Postlethwaite, E. J. Rohling, W. J. Jenkins and C. F. Walker: *Deep-Sea Res. II*, **52**, 1648 (2005).

32) , , : ° ع د GEOTRACES , pp 10 11, 2009 1 22 , (2009).

33) C. R. Riser, M. J. Warner and G. I. Yurasov: *J. Oceanogr.* **55**, 133 (1999).

34) Y. W. Watanabe, S. Watanabe and S. Tsunogai: *Mar. Chem.* **34**, 97 (1991).

35) , , , أ : , **74**, 172 (1999).

36) K. Harada, S. Tsunogai: *Earth Planet. Sci. Lett.* **77**, 236 (1986).

37) Y. Kumamoto, T. Aramaki, S. Watanabe, M. Yoneda, Y. Shibata, O. Togawa, M. Morita, K. Shitashima: *J. Oceanogr.* **64**, 429 (2008).

38) T. Senjyu, H. R. Shin, J. H. Yoon, Z. Nagano, H. S. An, S. K. Byun, C. K. Lee: *Deep-Sea Res. II* **52**, 1726 (2005).