

Supplement of Biogeosciences, 14, 3171–3189, 2017  
<https://doi.org/10.5194/bg-14-3171-2017-supplement>  
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*Supplement of*

## **Improving the inverse modeling of a trace isotope: how precisely can radium-228 fluxes toward the ocean and submarine groundwater discharge be estimated?**

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Table S1: Global list of  $^{228}\text{Ra}$  data sources. Sources not previously used are in bold

Location	Reference
Atlantic ocean	<i>Broecker et al. (1973)</i>
	<i>Moore (1981)</i>
	<i>Reid and Sackett (1982)</i>
	<i>Key et al. (1985)</i>
	<i>Moore (1987)</i>
	<i>Moore and Todd (1993)</i>
	<i>Moore and Shaw (1998)</i>
	<i>Nozaki et al. (1998)</i>
	<i>Rasmussen (2003)</i>
	<i>Moore (2006)</i>
	<i>Charette et al. (2007)</i>
	<i>Moore (2007)</i>
	<i>van Beek et al. (2007)</i>
	<i>Moore and de Oliveira (2008)</i>
	<i>Moore et al. (2008)</i>
	<i>van Beek et al. (2009)</i>
	<i>Schmidt et al. (2011)</i>
<i>Smoak et al. (2012)</i>	
<b><i>Charette et al. (2015)</i></b>	
<b><i>Rodellas et al. (2015)</i></b>	
<i>TTO [1981-1989]</i>	
North Pacific Ocean	<i>Moore (1969)</i>
	<i>Broecker et al. (1973)</i>
	<i>Kaufman et al. (1973)</i>
	<i>Knauss et al. (1978)</i>
	<i>Okubo (1980)</i>
	<i>Yamada and Nozaki (1986)</i>
	<i>Nozaki et al. (1990)</i>
	<i>Ku et al. (1995)</i>
	<i>Luo et al. (1995)</i>
	<i>Yeh and Chung (1997)</i>
	<i>Huh and Ku (1998)</i>
	<i>Nozaki et al. (1998)</i>
	<i>Nozaki and Yamamoto (2001)</i>
	<i>Cai et al. (2002)</i>
	<i>Kim et al. (2005)</i>
	<i>Kawakami and Kusakabe (2008)</i>
	<i>Chen et al. (2010)</i>
	<i>Liu et al. (2012)</i>
<i>Su et al. (2013)</i>	
<i>Lee et al. (2014)</i>	
<i>Moore et al. [unpublished]</i>	
<b><i>van Beek et al. [unpublished]</i></b>	

South Pacific Ocean	<p>Moore (1969)          Broecker et al. (1973)          Kaufman et al. (1973)          Knauss et al. (1978)          Ku et al. (1995)          Luo et al. (1995)          Charette et al. [unpublished]          Moore et al. [unpublished]  <b>GEOTRACES GP16 [unpublished]</b></p>
Indian Ocean	<p>Moore (1969)          Broecker et al. (1973)          Kaufman et al. (1973)          Moore (1997)          Nozaki et al. (1998)          Nozaki and Yamamoto (2001)          Rengarajan et al. (2002)          Loveless et al. (2008)  <b>Koch-Larrouy et al. (2015)</b>          Moore et al. [unpublished]</p>
Arctic Ocean	<p>Broecker et al. (1973)          Kaufman et al. (1973)  <b>Rutgers van der Loeff et al. (1995)</b>          Rutgers van der Loeff et al. (2003)  <b>Smith et al. (2003)</b>  <b>Kadko and Muench (2005)</b>  <b>Rutgers van der Loeff et al. (2012)</b></p>
Southern Ocean	<p>Kaufman et al. (1973)  <b>Hanfland (2002)</b>  <b>van Beek et al. (2008)</b>          Dulaiova et al. (2009)  <b>Annett et al. (2012)</b>  <b>Sanial et al. (2014)</b>  <b>Sanial et al. (2015)</b>          Charette et al. [unpublished]</p>

## References

- Annett, A. L., Henley, S. F., Van Beek, P., Souhaut, M., Ganeshram, R., Venables, H. J., Meredith, M. P., and Geibert, W.: Use of radium isotopes to estimate mixing rates and trace sediment inputs to surface waters in northern Marguerite Bay, Antarctic Peninsula, *Antarctic Science*, 25, 445–456, doi:10.1017/s0954102012000892, <https://doi.org/10.1017/S0954102012000892>, 2012.
- 5 Broecker, W. S., Kaufman, A., and Trier, R. M.: The residence time of thorium in surface sea water and its implications regarding the rate of reactive pollutants, *Earth and Planetary Science Letters*, 20, 35–44, doi:10.1016/0012-821x(73)90137-4, [https://doi.org/10.1016/0012-821x\(73\)90137-4](https://doi.org/10.1016/0012-821x(73)90137-4), 1973.
- Cai, P., Huang, Y., Chen, M., Guo, L., Liu, G., and Qiu, Y.: New production based on  $^{228}\text{Ra}$ -derived nutrient budgets and thorium-estimated POC export at the intercalibration station in the South China Sea, *Deep Sea Research Part I: Oceanographic Research Papers*, 49, 53–66, doi:10.1016/S0967-0637(01)00040-1, [https://doi.org/10.1016/S0967-0637\(01\)00040-1](https://doi.org/10.1016/S0967-0637(01)00040-1), 2002.
- 10 Charette, M. A., Gonneea, M. E., Morris, P. J., Statham, P., Fones, G., Planquette, H., Salter, I., and Garabato, A. N.: Radium isotopes as tracers of iron sources fueling a Southern Ocean phytoplankton bloom, *Deep Sea Research Part II: Topical Studies in Oceanography*, 54, 1989–1998, doi:10.1016/j.dsr2.2007.06.003, <https://doi.org/10.1016/j.dsr2.2007.06.003>, 2007.
- Charette, M. A., Morris, P. J., Henderson, P. B., and Moore, W. S.: Radium isotope distributions during the US GEOTRACES North Atlantic cruises, *Marine Chemistry*, 177, 184–195, doi:10.1016/j.marchem.2015.01.001, <https://doi.org/10.1016/j.marchem.2015.01.001>, 2015.
- 15 Chen, W., Liu, Q., Huh, C.-A., Dai, M., and Miao, Y.-C.: Signature of the Mekong River plume in the western South China Sea revealed by radium isotopes, *Journal of Geophysical Research*, 115, C12 002, doi:10.1029/2010jc006460, <https://doi.org/10.1029/2010JC006460>, 2010.
- Dulaiova, H., Ardelan, M. V., Henderson, P. B., and Charette, M. A.: Shelf-derived iron inputs drive biological productivity in the southern Drake Passage, *Global Biogeochemical Cycles*, 23, GB4014, doi:10.1029/2008gb003406, <https://doi.org/10.1029/2008GB003406>, 2009.
- 20 Hanfland, C.: Radium-226 and Radium-228 in the Atlantic Sector of the Southern Ocean, *Berichte zur Polar- und Meeresforschung*, 431, 1–135, doi:10.2312/BzPM\_0431\_2002, [https://doi.org/10.2312/BzPM\\_0431\\_2002](https://doi.org/10.2312/BzPM_0431_2002), 2002.
- Huh, C.-A. and Ku, T.-L.: A 2-D section of the  $^{228}\text{Ra}$  and  $^{226}\text{Ra}$  in the Northeast Pacific, *Oceanologica Acta*, 21, 533–542, doi:10.1016/S0399-1784(98)80036-4, [https://doi.org/10.1016/S0399-1784\(98\)80036-4](https://doi.org/10.1016/S0399-1784(98)80036-4), 1998.
- 25 Kadko, D. and Muench, R.: Evaluation of shelf-basin interaction in the western Arctic by use of short-lived radium isotopes: The importance of mesoscale processes, *Deep Sea Research Part II: Topical Studies in Oceanography*, 52, 3227–3244, doi:10.1016/j.dsr2.2005.10.008, <https://doi.org/10.1016/j.dsr2.2005.10.008>, 2005.
- Kaufman, A., Trier, R. M., and Broecker, W. S.: Distribution of  $^{228}\text{Ra}$  in the World Ocean, *Journal of Geophysical Research*, 78, 8827–8848, doi:10.1029/jc078i036p08827, <https://doi.org/10.1029/jc078i036p08827>, 1973.
- 30 Kawakami, H. and Kusakabe, M.: Surface water mixing estimated from  $^{228}\text{Ra}$  and  $^{226}\text{Ra}$  in the northwestern North Pacific, *Journal of Environmental R*, 99, 1335–1340, doi:10.1016/j.jenvrad.2008.04.011, <https://doi.org/10.1016/j.jenvrad.2008.04.011>, 2008.
- Key, R. M., Stallard, R. F., Moore, W. S., and Sarmiento, J. L.: Distribution and Flux of  $^{226}\text{Ra}$  and  $^{228}\text{Ra}$  in the Amazon River Estuary, *Journal of Geophysical Research*, 90, 6995–7004, doi:10.1029/jc090ic04p06995, <https://doi.org/10.1029/jc090ic04p06995>, 1985.
- 35 Kim, G., Ryu, J.-W., Yang, H.-S., and Yun, S.-T.: Submarine groundwater discharge (SGD) into the Yellow Sea revealed by  $^{228}\text{Ra}$  and  $^{226}\text{Ra}$  isotopes: Implications for global silicate fluxes, *Earth and Planetary Science Letters*, 237, 156–166, doi:10.1016/j.epsl.2005.06.011, <https://doi.org/10.1016/j.epsl.2005.06.011>, 2005.
- Knauss, K. G., Ku, T.-L., and Moore, W. S.: Radium and Thorium isotopes in the surface waters of the east Pacific and coastal Southern California, *Earth and Planetary Science Letters*, 39, 235–249, doi:10.1016/0012-821x(78)90199-1, [https://doi.org/10.1016/0012-821x\(78\)90199-1](https://doi.org/10.1016/0012-821x(78)90199-1), 1978.
- 40 Koch-Larrouy, A., Atmadipoera, A., van Beek, P., Madec, G., Aucan, J., Lyard, F., Grelet, J., and Souhaut, M.: Estimates of tidal mixing in the Indonesian archipelago from multidisciplinary INDOMIX in-situ data, *Deep Sea Research Part I: Oceanographic Research Papers*, 106, 136–153, doi:10.1016/j.dsr.2015.09.007, <https://doi.org/10.1016/j.dsr.2015.09.007>, 2015.
- Ku, T.-L., Luo, S., Kusakabe, M., and Bishop, J. K. B.:  $^{228}\text{Ra}$ -derived nutrient budgets in the upper equatorial Pacific and the role of "new" silicate in limiting productivity, *Deep Sea Research Part II: Topical Studies in Oceanography*, 42, 479–497, doi:10.1016/0967-0645(95)00020-Q, [https://doi.org/10.1016/0967-0645\(95\)00020-Q](https://doi.org/10.1016/0967-0645(95)00020-Q), 1995.
- 45 Lee, H., Kim, G., Kim, J., Park, G., and Song, K.-H.: Tracing the flow rate and mixing ratio of the Changjiang diluted water in the northwestern Pacific marginal seas using radium isotopes, *Geophysical Research Letters*, 41, 4637–4645, doi:10.1002/2014gl060230, <https://doi.org/10.1002/2014GL060230>, 2014.
- 50 Liu, Q., Dai, M., Chen, W., Huh, C.-A., Wang, G., Li, Q., and Charette, M. A.: How significant is submarine groundwater discharge and its associated dissolved inorganic carbon in a river-dominated shelf system?, *Biogeosciences*, 9, 1777–1795, doi:10.5194/bg-9-1777-2012, <https://doi.org/10.5194/bg-9-1777-2012>, 2012.

- Loveless, A. M., Oldham, C. E., and Hancock, G. J.: Radium isotopes reveal seasonal groundwater inputs to Cockburn Sound, a marine embayment in Western Australia, *Journal of Hydrology*, 351, 203–217, doi:10.1016/j.jhydrol.2007.12.010, <https://doi.org/10.1016/j.jhydrol.2007.12.010>, 2008.
- 5 Luo, S., Ku, T.-L., Kusakabe, M., Bishop, J. K. B., and Yang, Y.-L.: Tracing particle cycling in the upper ocean with  $^{230}\text{Th}$  and  $^{228}\text{Th}$ : Ann investigation in the equatorial Pacific along 140°W, *Deep Sea Research Part II: Topical Studies in Oceanography*, 42, 805–829, doi:10.1016/0967-0645(95)00019-M, [https://doi.org/10.1016/0967-0645\(95\)00019-M](https://doi.org/10.1016/0967-0645(95)00019-M), 1995.
- Moore, W. S.: Oceanic concentrations of  $^{228}\text{Ra}$ , *Earth and Planetary Science Letters*, 6, 437–446, doi:10.1016/0012-821x(69)90113-7, [https://doi.org/10.1016/0012-821x\(69\)90113-7](https://doi.org/10.1016/0012-821x(69)90113-7), 1969.
- Moore, W. S.: Radium Isotopes in the Chesapeake Bay, *Estuarine, Coastal and Shelf Science*, 12, 713–723, doi:10.1016/s0302-3524(81)80067-9, [https://dx.doi.org/10.1016/s0302-3524\(81\)80067-9](https://dx.doi.org/10.1016/s0302-3524(81)80067-9), 1981.
- 10 Moore, W. S.: Radium 228 in the South and Atlantic Bight, *Journal of Geophysical Research*, 92, 5177–5190, doi:10.1029/JC092iC05p05177, <https://doi.org/10.1029/JC092iC05p05177>, 1987.
- Moore, W. S.: High fluxes of radium and barium from the mouth of the Ganges–Brahmaputra River during low river discharge suggest a large groundwater source, *Earth and Planetary Science Letters*, 150, 141–150, doi:10.1016/S0012-821X(97)00083-6, [https://doi.org/10.1016/S0012-821X\(97\)00083-6](https://doi.org/10.1016/S0012-821X(97)00083-6), 1997.
- 15 Moore, W. S.: Radium isotopes as tracers of submarine groundwater discharge in Sicily, *Continental Shelf Research*, 26, 852–861, doi:10.1016/j.csr.2005.12.004, <https://doi.org/10.1016/j.csr.2005.12.004>, 2006.
- Moore, W. S.: Seasonal distribution and flux of radium isotopes on the southeastern U.S. continental shelf, *Journal of Geophysical Research*, 112, C10013, doi:10.1029/2007jc004199, <https://doi.org/10.1029/2007JC004199>, 2007.
- 20 Moore, W. S. and de Oliveira, J.: Determination of residence time and mixing processes of the Ubatuba, Brazil, inner shelf waters using natural Ra isotopes, *Estuarine, Coastal and Shelf Science*, 76, 512–521, doi:10.1016/j.ecss.2007.07.042, <https://doi.org/10.1016/j.ecss.2007.07.042>, 2008.
- Moore, W. S. and Shaw, T. J.: Chemical signals from submarine fluid advection onto the continental shelf, *Journal of Geophysical Research: Oceans*, 103, 21 543–21 552, doi:10.1029/98jc02232, <https://doi.org/10.1029/98JC02232>, 1998.
- 25 Moore, W. S. and Todd, J. F.: Radium Isotopes in the Orinoco Estuary and the Eastern Caribbean Sea, *Journal of Geophysical Research*, 98, 2233–2244, doi:10.1029/92JC02760, <https://doi.org/10.1029/92JC02760>, 1993.
- Moore, W. S., Sarmiento, J. L., and Key, R. M.: Submarine groundwater discharge revealed by  $^{228}\text{Ra}$  distribution in the upper Atlantic Ocean, *Nature Geosci*, 1, 309–311, doi:10.1038/ngeo183, <https://doi.org/10.1038/ngeo183>, 2008.
- Nozaki, Y. and Yamamoto, Y.: Radium 228 based nitrate fluxes in the east Indian Ocean and the South China Sea and a silicon-induced "alkalinity pump" hypothesis, *Global Biogeochemical Cycles*, 15, 555–567, doi:10.1029/2000gb001309, <https://doi.org/10.1029/2000gb001309>, 2001.
- 30 Nozaki, Y., Kasemsupaya, V., and Tsubota, H.: The distribution of  $^{228}\text{Ra}$  and  $^{226}\text{Ra}$  in the surface waters of the northern North Pacific, *Geochemical Journal*, 24, 1–6, doi:10.2343/geochemj.24.1, <https://doi.org/10.2343/geochemj.24.1>, 1990.
- Nozaki, Y., Dobashi, F., Kato, Y., and Yamamoto, Y.: Distribution of Ra and isotopes and the  $^{210}\text{Pb}$  and  $^{210}\text{Po}$  balance in surface seawaters of the mid Northern Hemisphere, *Deep Sea Research Part I: Oceanographic Research Papers*, 45, 1263–1284, doi:10.1016/S0967-0637(98)00016-8, [https://doi.org/10.1016/S0967-0637\(98\)00016-8](https://doi.org/10.1016/S0967-0637(98)00016-8), 1998.
- 35 Okubo, T.: Radium-228 in the Japan Sea, *Journal of the Oceanographical Society of Japan*, 36, 263–268, doi:10.1007/bf02072128, <https://doi.org/10.1007/bf02072128>, 1980.
- Rasmussen, L. L.: Radium Isotopes as Tracers of Coastal Circulation Pathways in the Mid-Atlantic Bight, Ph.D. thesis, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, 2003.
- 40 Reid, D. F. and Sackett, W. M.: Radium in the near-surface Caribbean Sea, *Earth and Planetary Science Letters*, 60, 17–26, doi:10.1016/0012-821X(82)90016-4, [https://doi.org/10.1016/0012-821X\(82\)90016-4](https://doi.org/10.1016/0012-821X(82)90016-4), 1982.
- Rengarajan, R., Sarin, M. M., Somayajulu, B. L. K., and Sushani, R.: Mixing in the surface waters of the western Bay of Bengal using  $^{228}\text{Ra}$  and  $^{226}\text{Ra}$ , *Journal of Marine Research*, 60, 255–279, doi:10.1357/00222400260497480, <https://doi.org/10.1357/00222400260497480>, 2002.
- 45 Rodellas, V., Garcia-Orellana, J., Masqué, P., Feldman, M., and Weinstein, Y.: Submarine groundwater discharge as a major source of nutrients to the Mediterranean Sea, *Proceedings of the National Academy of Sciences of the United States of America*, 112, 3926–3930, doi:10.1073/pnas.1419049112, <https://doi.org/10.1073/pnas.1419049112>, 2015.
- Rutgers van der Loeff, M., Kühne, S., Wahsner, M., Hölzner, H., Frank, M., Ekwurzel, B., Mensch, M., and Rachold, V.:  $^{228}\text{Ra}$  and  $^{226}\text{Ra}$  and in the Kara and Laptev seas, *Continental Shelf Research*, 23, 113–124, doi:10.1016/s0278-4343(02)00169-3, [https://doi.org/10.1016/s0278-4343\(02\)00169-3](https://doi.org/10.1016/s0278-4343(02)00169-3), 2003.
- 50

- Rutgers van der Loeff, M., Cai, P., Stimac, I., Bauch, D., Hanfland, C., Roeske, T., and Moran, S. B.: Shelf-basin exchange times of Arctic surface waters estimated from  $^{228}\text{Th}/^{228}\text{Ra}$  disequilibrium, *Journal of Geophysical Research: Oceans*, 117, C03 024, doi:10.1029/2011jc007478, <https://doi.org/10.1029/2011JC007478>, 2012.
- 5 Rutgers van der Loeff, M. M., Key, R. M., Scholten, J., Bauch, D., and Michel, A.:  $^{228}\text{Ra}$  as a tracer for shelf water in the Arctic Ocean, *Deep-Sea Research II*, 42, 1533–1553, doi:10.1016/0967-0645(95)00053-4, [https://doi.org/10.1016/0967-0645\(95\)00053-4](https://doi.org/10.1016/0967-0645(95)00053-4), 1995.
- Sanial, V., van Beek, P., Lansard, B., d’Ovidio, F., Kestenare, E., Souhaut, M., Zhou, M., and Blain, S.: Study of the phytoplankton plume dynamics off the Crozet Islands (Southern Ocean): A geochemical-physical coupled approach, *Journal of Geophysical Research: Oceans*, 119, 2227–2237, doi:10.1002/2013jc009305, <https://doi.org/10.1002/2013JC009305>, 2014.
- 10 Sanial, V., van Beek, P., Lansard, B., Souhaut, M., Kestenare, E., d’Ovidio, F., Zhou, M., and Blain, S.: Use of Ra isotopes to deduce rapid transfer of sediment-derived inputs off Kerguelen, *Biogeosciences*, 12, 1415–1430, doi:10.5194/bg-12-1415-2015, <https://doi.org/10.5194/bg-12-1415-2015>, 2015.
- Schmidt, C., Hanfland, C., Regnier, P., Van Cappellen, P., Schlüter, M., Knauth, U., Stimac, I., and Geibert, W.:  $^{228}\text{Ra}$ ,  $^{226}\text{Ra}$ ,  $^{224}\text{Ra}$  and  $^{223}\text{Ra}$  in potential sources and sinks of land-derived material in the German Bight of the North Sea: implications for the use of radium as a tracer, *Geo-Marine Letters*, 31, 259–269, doi:10.1007/s00367-011-0231-5, <https://doi.org/10.1007/s00367-011-0231-5>, 2011.
- 15 Smith, J., Moran, S., and Macdonald, R.: Shelf-basin interactions in the Arctic Ocean based on  $^{210}\text{Pb}$  and Ra isotope tracer distributions, *Deep Sea Research Part I: Oceanographic Research Papers*, 50, 397–416, doi:10.1016/s0967-0637(02)00166-8, [https://doi.org/10.1016/S0967-0637\(02\)00166-8](https://doi.org/10.1016/S0967-0637(02)00166-8), 2003.
- Smoak, J. M., Sanders, C. J., Patchineelam, S. R., and Moore, W. S.: Radium mass balance and submarine groundwater discharge in Sepetiba Bay, Rio de Janeiro State, Brazil, *Journal of South American Earth Sciences*, 39, 44–51, doi:10.1016/j.jsames.2012.07.004, <https://doi.org/10.1016/j.jsames.2012.07.004>, 2012.
- 20 Su, N., Du, J., Li, Y., and Zhang, J.: Evaluation of surface water mixing and associated nutrient fluxes in the East China Sea using  $^{226}\text{Ra}$  and  $^{228}\text{Ra}$ , *Marine Chemistry*, 156, 108–119, doi:10.1016/j.marchem.2013.04.009, <https://doi.org/10.1016/j.marchem.2013.04.009>, 2013.
- van Beek, P., François, R., Conte, M., Reyss, J.-L., Souhaut, M., and Charette, M.:  $^{228}\text{Ra}/^{226}\text{Ra}$  and  $^{226}\text{Ra}/\text{Ba}$  ratios to track barite formation and transport in the water column, *Geochimica et Cosmochimica Acta*, 71, 71–86, doi:10.1016/j.gca.2006.07.041, <https://doi.org/10.1016/j.gca.2006.07.041>, 2007.
- 25 van Beek, P., Bourquin, M., Reyss, J.-L., Souhaut, M., Charette, M., and Jeandel, C.: Radium isotopes to investigate the water mass pathways on the Kerguelen Plateau (Southern Ocean), *Deep Sea Research Part II: Topical Studies in Oceanography*, 55, 622–637, doi:10.1016/j.dsr2.2007.12.025, <https://doi.org/10.1016/j.dsr2.2007.12.025>, 2008.
- van Beek, P., Sternberg, E., Reyss, J.-L. and Souhaut, M., Robin, E., and Jeandel, C.:  $^{228}\text{Ra}/^{226}\text{Ra}$  and  $^{226}\text{Ra}/\text{Ba}$  ratios in the Western Mediterranean Sea: barite formation and transport in the water column, *Geochimica et Cosmochimica Acta*, 73, 4720–4737, doi:10.1016/j.gca.2009.05.063, <https://dx.doi.org/10.1016/j.gca.2009.05.063>, 2009.
- 30 Yamada, M. and Nozaki, Y.: Radium isotopes in coastal and open ocean surface waters of the Western North Pacific, *Marine Chemistry*, 19, 379–389, doi:10.1016/0304-4203(86)90057-5, [https://doi.org/10.1016/0304-4203\(86\)90057-5](https://doi.org/10.1016/0304-4203(86)90057-5), 1986.
- Yeh, J. C. and Chung, Y. C.:  $^{228}\text{Ra}$  and  $^{226}\text{Ra}$  distributions off north and southwest Taiwan, *Terrestrial, Atmospheric and Oceanic Sciences*, 8, 141, doi:10.3319/tao.1997.8.1.141(o), [https://doi.org/10.3319/tao.1997.8.1.141\(o\)](https://doi.org/10.3319/tao.1997.8.1.141(o)), 1997.
- 35