Duke of Edinburgh Prize to:

Eitaro WADA

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for "Elucidation of Ecosystem Structure and its Response to Environmental Change with Special Reference to the Stable Isotope Fingerprint"

Outline of the work:

Dr. Eitaro Wada has been involved in research concerning the abundance of nitrogen and carbon isotopic ratios in various kinds of ecosystems for over 40 years. He proposed ca. 10 empirical laws of the distribution of N and C isotopes and substantially advanced the unification of isotope biogeochemistry and isotope ecology by introducing the following general equations:

$$\delta^{15}\mathrm{N}\ (\text{animal}) = 3.3\ (\text{Trophic Level} - 1) + \delta^{15}\mathrm{N}\ (\text{plant})$$

$$\delta^{13}\mathrm{C}\ (\text{animal}) = 1.\mathrm{n}\ (\text{Trophic Level} - 1) + \delta^{15}\mathrm{N}\ (\text{plant})$$

Here, n ranges from 0.0 to 0.2 and TL is trophic level (plant = 1.0).

The $\delta^{15}\mathrm{N}$ — $\delta^{13}\mathrm{C}$ map provides a useful model of food web structures in natural ecosystems. This research, together with the development of the Isotope Ratio Mass Spectrometer, has greatly advanced the understanding of food web structures and population ecology, enabling simultaneous analysis of the structure and material cycling of ecosystems. Dr. Wada's research played a pioneering role in the unification of ecosystem ecology and isotope biogeochemistry.

Results from Dr. Wada's research have been applied in other scientific research fields, such as the study of food habit structure in archaeology and in the contemporary environment, the so-called traceability of stable isotopes under environmental issues. Dr. Wada has extensive experience in fieldwork in both terrestrial and marine ecosystems. With this background, he became project leader for three major research projects that investigated material cycling and ecosystem change in watersheds with emphasis on nitrogen and carbon cycles. He developed new avenues on stable isotope indicators and environmental capacity, which elucidate the dynamic interactions between natural and social systems.

Pioneering works on natural abundance of nitrogen isotope ratio

Measurement of the nitrogen isotope ratio at ambient levels was an extremely challenging research subject in 1960's because of contamination of atmospheric nitrogen and carbon monooxide.

Overcoming this challenge, Dr. Wada succeeded in the measurement of nitrogen isotope ratio in natural ecosystems. His key results are summarised as follows:

- Marine ecosystems exhibited higher $^{15}\mathrm{N}$ content than corresponding terrestrial ecosystems due to the occurrence of denitrification ($NO_3 \rightarrow N_2$) in anoxic water mass in open ocean, while the lowest $^{15}\mathrm{N}/^{14}\mathrm{N}$ (low $\delta^{15}\mathrm{N}$) in the biosphere was found for algae in a saline pond located in Dry Valleys,

Victorialand, Antarctica.

- Finding of trophic effect: stepwise enrichment of ^{15}N along the food chain.
- Elucidation of the major marine nitrogen cycle by analyzing the mass balance of ^{15}N.

These results provided a new avenue for nitrogen isotope biogeochemistry and ecosystem ecology throughout the world.

Measurements of nitrogen kinetic isotope effects for major nitrogen metabolisms and development of the scientific field of isotope ecology

Dr. Wada measured nitrogen and carbon isotope effects for a diverse set of metabolic processes involving nitrification, denitrification, N_2 fixation, algal culture of diatoms and paddy soil incubation to clarify the production mechanisms of green house gases. The results clarified the framework for the nitrogen and carbon cycles on the basis of stable isotopes. He determined a general equation for describing the feeding process irrespective of the animal life form (vertebrate or invertebrate) as follows:

$$\delta^{15}N \text{ (animal)} = 3.3 \text{ (Trophic Level} - 1) + \delta^{15}N \text{ (plant)}$$

The equation was confirmed in various kinds of aquatic ecosystems including the Pacific Ocean, Antarctic Ocean, Lake Baikal, Lake Biwa, and various wetlands and cultivated fields. The above equation and isotope effects for various biogeochemical processes make it possible to unify the analysis of material cycles and food webs.

Current progress in isotope ratio mass spectrometry also led to the development of a simple and quick online method to measure simultaneously the nitrogen and carbon isotope ratios. Isotope ecology has become a common method, comparable to DNA analysis, in ecology today.

Promotion of major projects addressing global environmental issues with emphasis on the response of terrestrial watersheds to environmental change and dynamic interaction of natural and social systems

After the 1990's Dr. Wada's research has focused on the restoration of human dominated watersheds including mountain forests, lakes, cultivated fields and coastal bays. Lake Biwa-Yodo River watershed is major target one. The following projects were conducted from 1997 to 2007 as Project Leader in 1, 3, 4 and a core member in P-2.

1. IGBP-MEXT & IGBP TEMA, Response of terrestrial watershed ecosystems to global changes.
2. MEXT New Creative Basic Research Program on Biodiversity Conservation.
3. JSPS-Program of Future Research, Developing standards for global monitoring through multidisciplinary study of a catchment area.
4. RIHN (Research Institute for Humanity & Nature) Project for understanding interactions between humans and nature in the Lake Biwa-Yodo River watershed.

Major results include:

- Elucidation of the response of watershed to increasing pCO2: from upper reaches of forest to middle reaches of lakes, for example, increases in numbers of leaf, tree height, photosynthetic activity during warm winter season.
- Propose of 'Stable Isotope Indicators' for assessing level of pollution and adequate population density to keep aerobic condition of rivers.

From the results of studies over 15 years on the Lake Biwa, Selenga River, Lake Baikal watersheds, a new framework of environmental studies is proposed to deepen the interaction between nature and humanity. Integrative studies of the observation, modeling and simulation may be connected to social management systems of the Plan-Do-Check-Action.

Present status

In his present position, Dr. Wada has continued his research to further develop stable isotope indicators and assess carrying capacity for small urban rivers. A major, mid-term goal of the Ecosystem Change Research Program (ECRP) of the Frontier Research Center for Global Change is to develop a biosphere sub-model for the integrated model of global change. In this context, Dr. Wada has directed the efforts of ECRP researchers with a focus on modeling of biogeochemical carbon cycles in both terrestrial and marine ecosystems. The research involves the application of remote sensing and advanced modeling and prediction with super computer systems. Dr. Wada's program at JAMSTEC FRCGC is the only ecosystem modeling group that could contribute effectively to the IPCC-Assessment Report 5 in 2012.

In summary, Dr. Wada has made honorable achievements to establish the field of isotope ecology, together with integration of material cycles of biophilic elements and ecosystem ecology with special reference to food web structure. Through his achievements, a new approach to studies of ecosystem function and biodiversity has become possible. Moreover, Dr. Wada has made significant contributions in proposing an effective approach to examining the dynamic interactions between human activities and natural ecosystems.

Selected publications

[1] Miyake, Y. and Wada, E. (1967) The abundance ratio of $^{15}N/^{14}N$ in marine environments. *Records of Oceanographic Works in Japan* 9(1): 37-53.

[2] Wada, E., Shibata, R., and Torii, T. (1981) ^{15}N abundance in Antarctica: origin of soil nitrogen and ecological implications. *Nature* 292: 327-329.

[3] Wada, E., Terazaki, M., Kabaya, Y., and Nemoto, T. (1986) ^{15}N and ^{13}C abundances in the Antarctic Ocean with emphasis on the biogeochemical structure of the food web. *Deep-Sea Research* 34: 829-841.

[4] Ogawa, O.N., Koitabashi, T., Oda, H., Nakamura, T., Ohkouchi, N., and Wada, E. (2001) Fluctuations of nitrogen isotope ratio of gobiid fish (Isaza) specimens and sediments in Lake Biwa, Japan, during the 20th century. *Limnology and Oceanography* 46(5): 1228-1236.

Books

[1] Wada, E. and Hattori, A. (1991) Nitrogen in the sea: forms, abundances & rate processes. CRC Press, Florida, U.S.A. 208pp.

[2] Wada, E., Ando, T., and Kumazawa, K. (1995) Biodiversity of stable isotope ratios. In: *Stable Isotopes in the Biosphere* (eds. Wada, E., Yoneyama, T., Minagawa, M., Ando, T., and Fry, B.D.). Kyoto University Press, pp. 7-14.