National Institute for Environmental Studies, Japan

Investigation of Cs migration and accumulation at a catchment scale

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- Results and interpretation of Cs migration and accumulation from investigations
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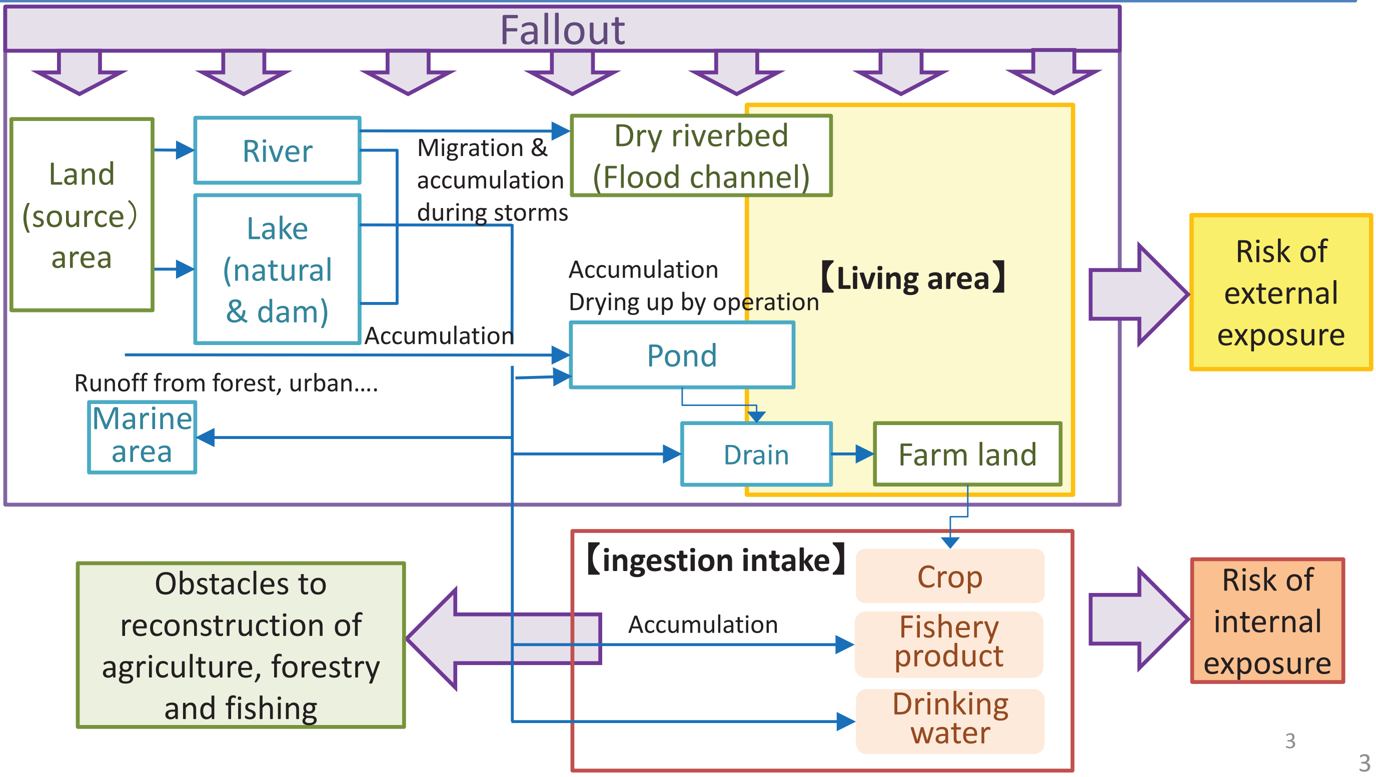
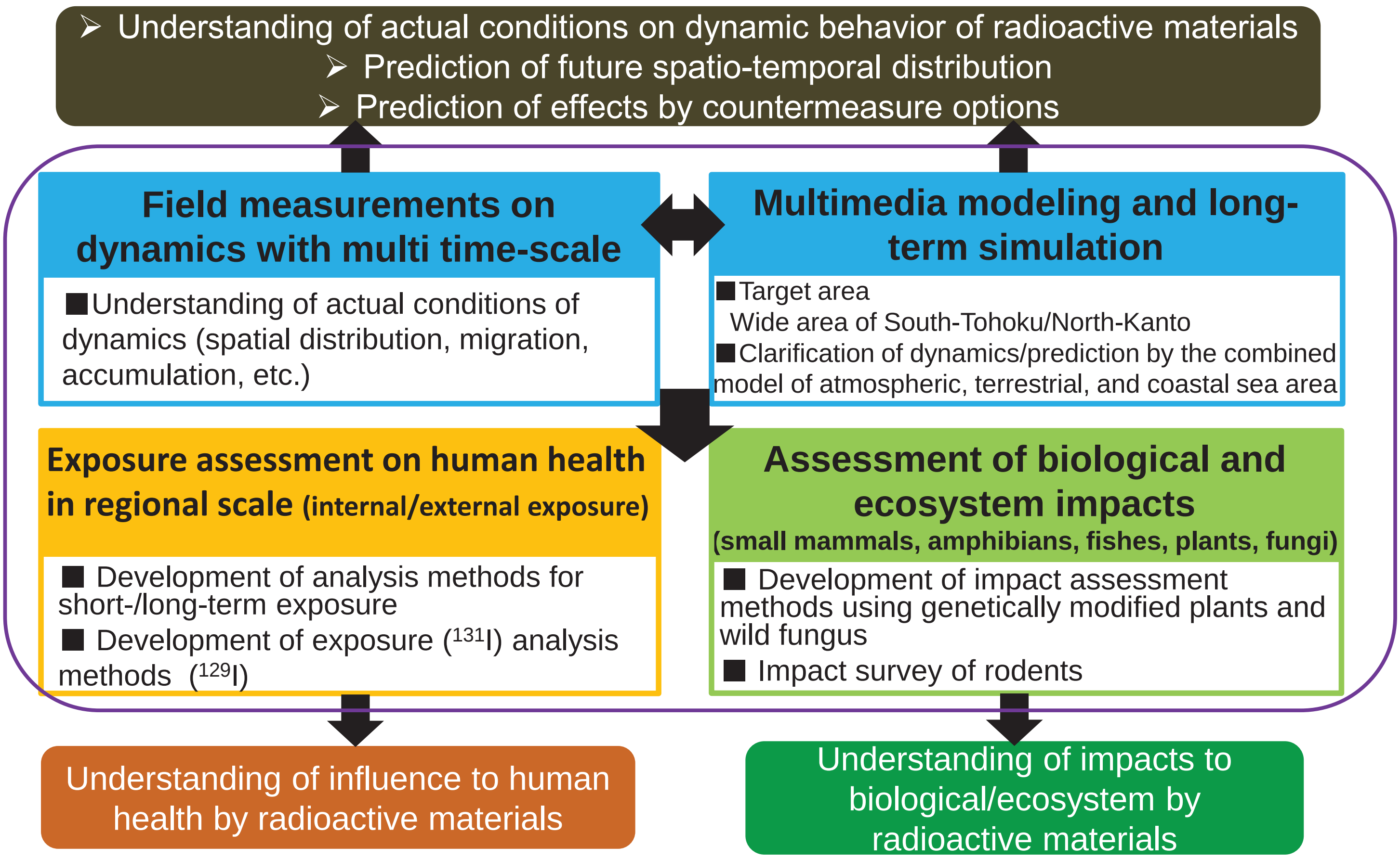
Understanding of radiation exposure pathway in river basin scale

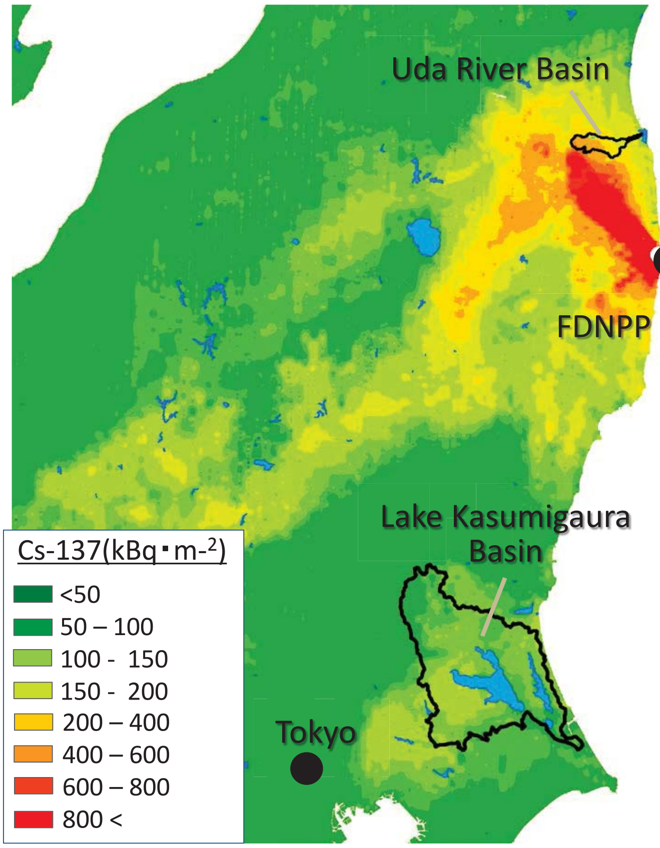
- Quantitative evaluation of Cs behavior to reduce risk of external and internal exposures
- Examination of contamination condition and effectiveness of countermeasures
  → Contribution to environmental recovery



NIES research project on radioactive substances in multimedia environments



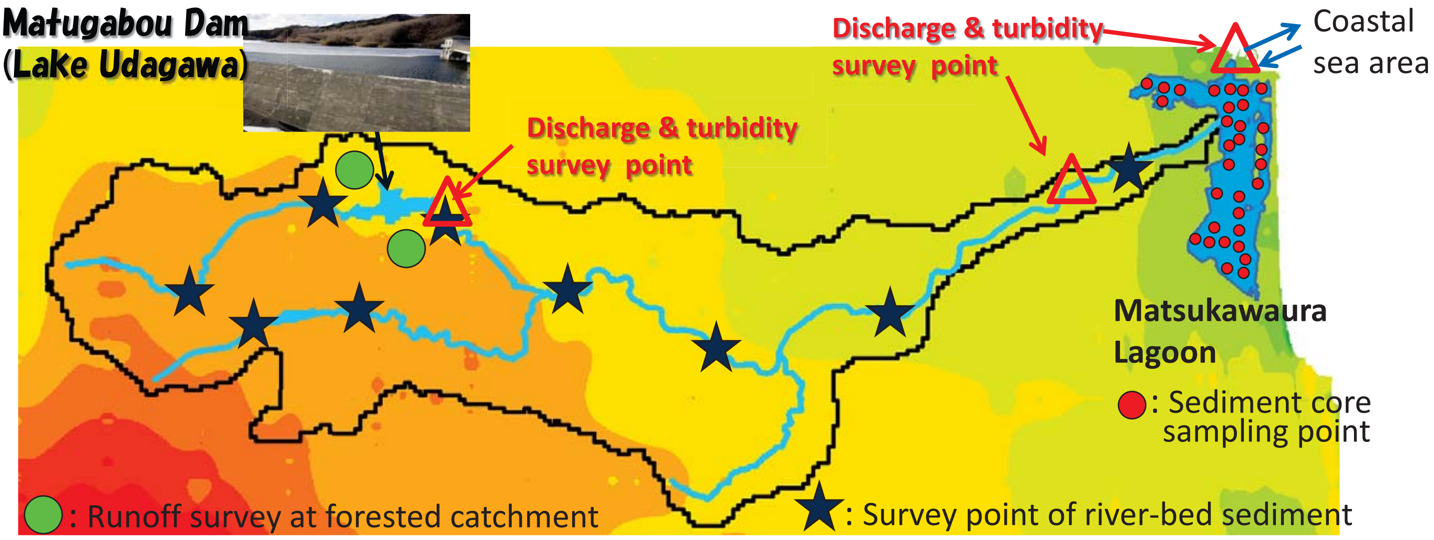
Study area



^{137}Cs deposition from an airborne monitoring survey on Nov. 11th, 2011

- Lake Kasumigaura Basin (2,157km^2) as a mildly-contaminated area
  - Shallow eutrophied lake with long retention time (200 days).
  - Still blocking shipment for some fishes
- Uda River Basin (106.3km^2) as a heavily-contaminated area
  - Highly contaminated mountainous upper region compared to lowland region
  - Dam (Matugabou dam) controlling water flow in the basin
  - Large coastal lagoon (Matsukawaura Lagoon)as an accumulation place

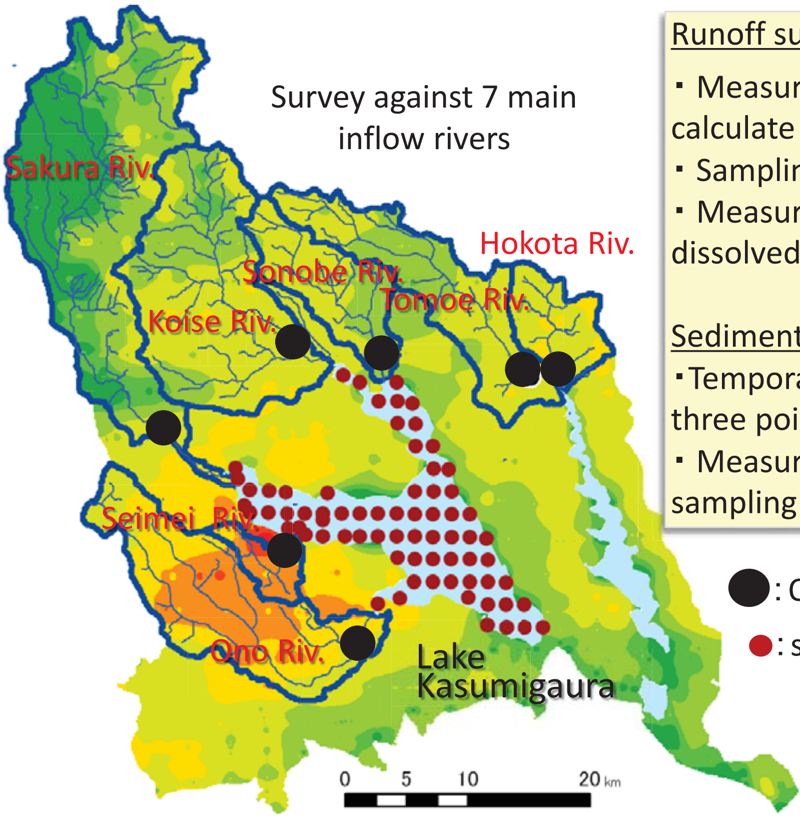
^{137}Cs flows & stocks survey in the Uda River Basin



Runoff survey
- ^{137}Cs runoff from forested area
- ^{137}Cs outflow flux from the upstream dam
- ^{137}Cs flux and runoff ratio from the whole basin

Sediment survey
- ^{137}Cs accumulation amount and profile in the bottoms of upstream dam
- Longitudinal variation of ^{137}Cs activity in the river-bed sediment
- Spatial distribution and total deposition of ^{137}Cs in the lagoon

^{137}Cs flows & stocks survey in the Lake Kasumigaura Basin



Runoff survey:

- Measuring flow rates, turbidities and SS conc. to calculate SS flux after the accident.
- Sampling river waters during rain runoff events
- Measuring ^{137}Cs activities associated with SS and dissolved

Sediment survey:

- Temporal change analysis by stationary sampled core at three points
- Measuring ^{137}Cs accumulation at 68 points by core sampling on Dec., 2012 and Oct., 2013

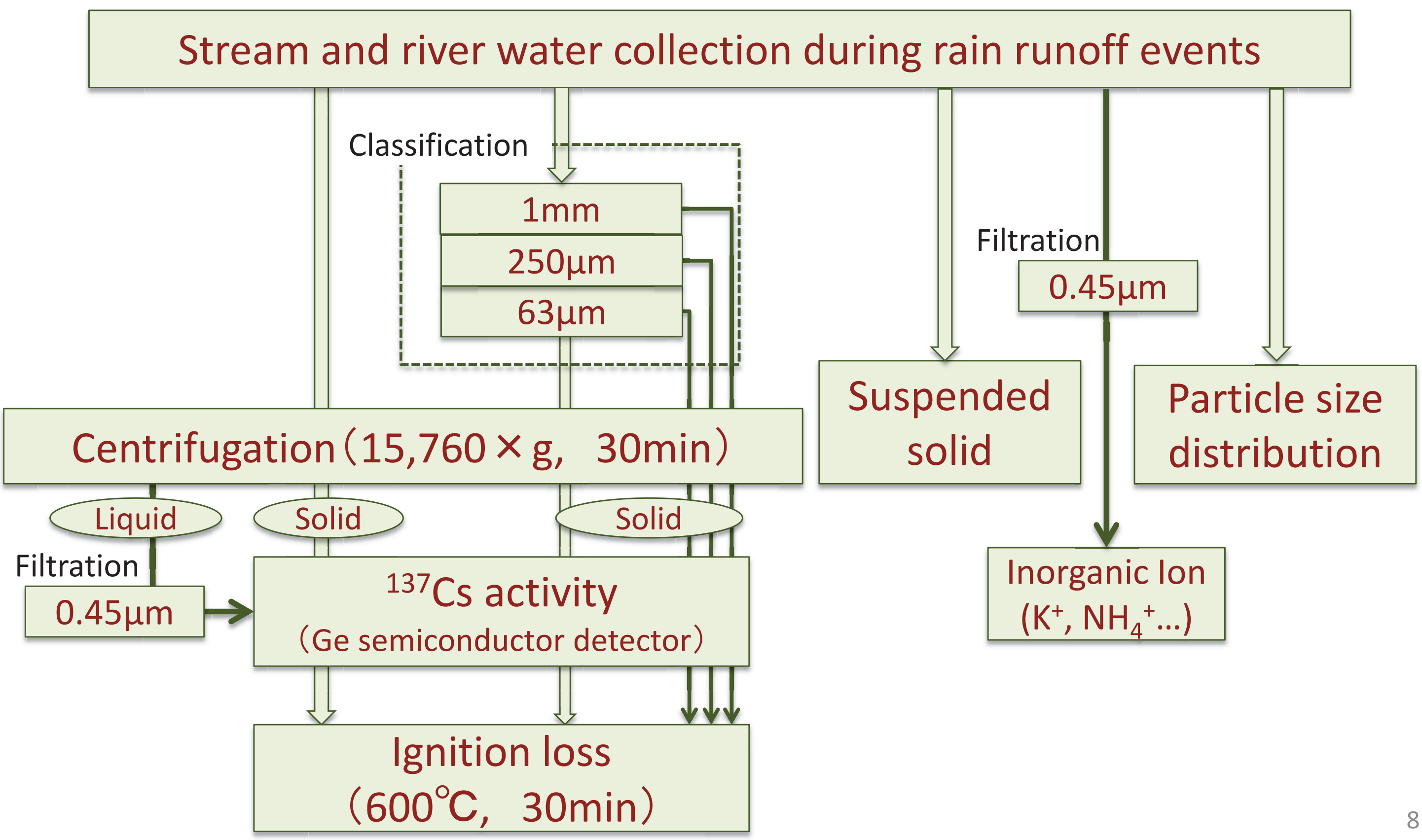
●: Observatory of flow rate and turbidity

●: sediment core sampling point

^{137}Cs accumulation in basin (Bq・m-2)

<2,500	20,000 – 30,000
2,500 – 5,000	30,000 – 40,000
5,000 - 10,000	40,000 – 50,000
10,000 - 20,000	50,000 <

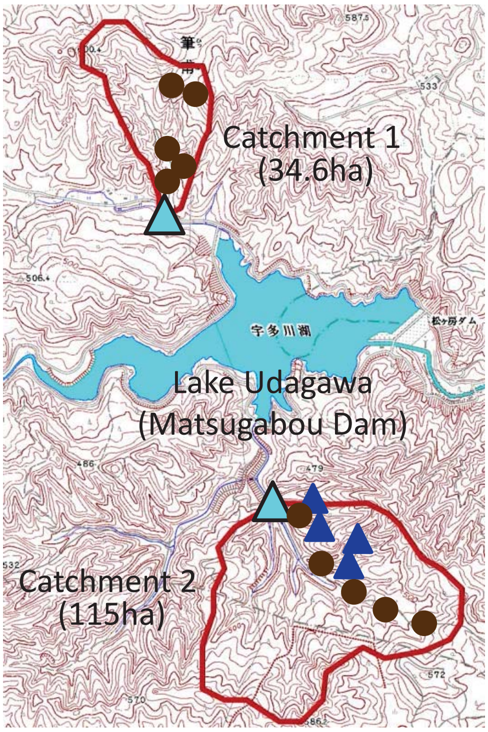
Analysis procedure for ^{137}Cs



Behavior of radioactive Cs in the Uda River Basin

Outline of survey in forested area

Survey starting from July, 2012

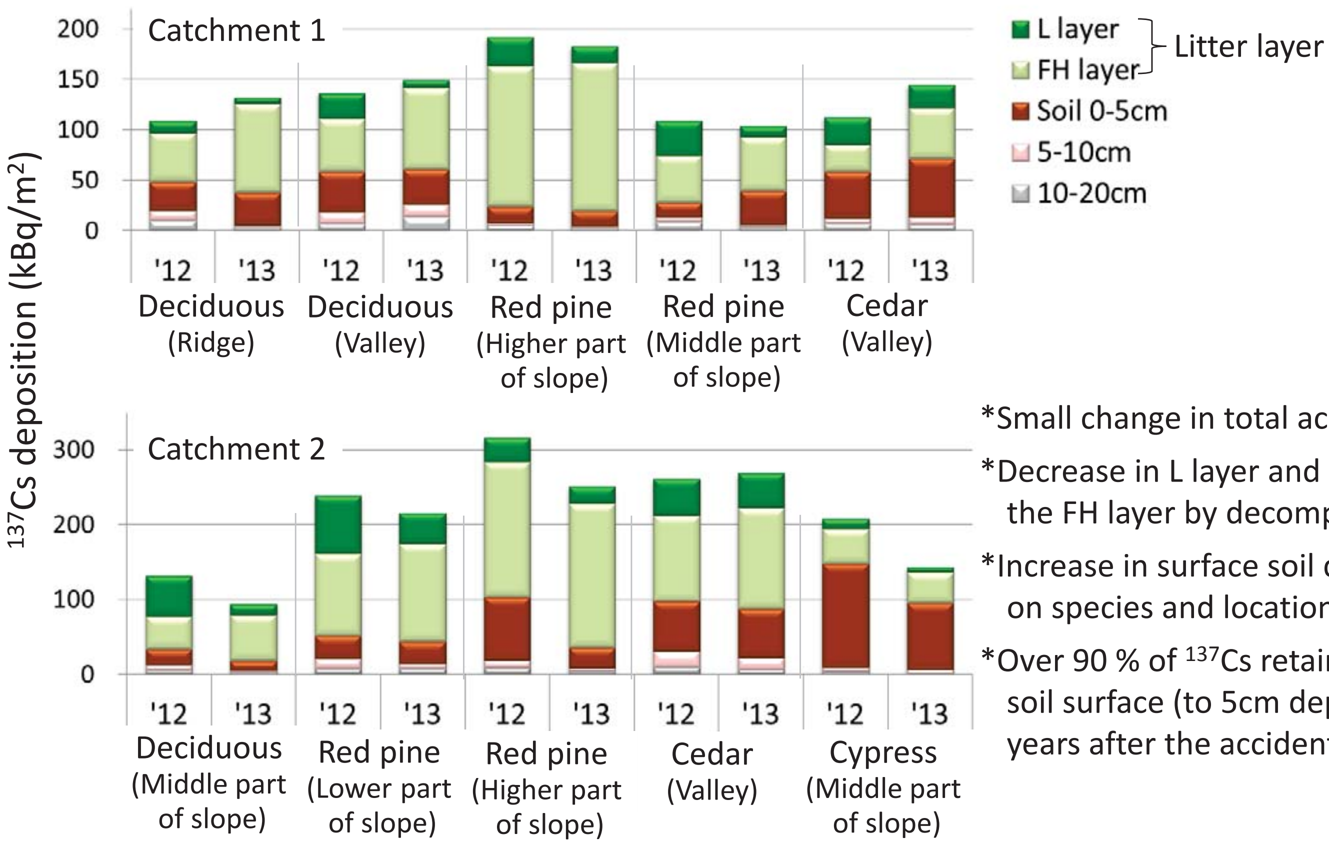


- ● ^{137}Cs accumulation in soil under various tree species

- ▲ ^{137}Cs runoff from plot scale under various tree species

- △ ^{137}Cs runoff from catchment scale

Annual change in ^{137}Cs accumulation in forest soil



*Small change in total accumulation

*Decrease in L layer and increase in the FH layer by decomposition

*Increase in surface soil depending on species and locations?

*Over 90 % of ^{137}Cs retained in the soil surface (to 5cm depth) in 2.5 years after the accident

^{137}Cs runoff from plot-scale in forest

Effect of tree species on ^{137}Cs runoff from catchment slope

Experimental method

- Plot: width 1.5m ×slope length 2m
- Period : May 24 to Oct. 16 in 2013 (145 days, precipitation amount: 720mm)
- Species : Cedar, Japanese Red Pine, Cypress, Deciduous broad-leaved tree
- Slope angle : 38±1°
- Sampling frequency : Monthly or after a large rainfall event
- Measurement item : runoff volume, sediment load, runoff amounts of sorbed and dissolved ^{137}Cs

Results

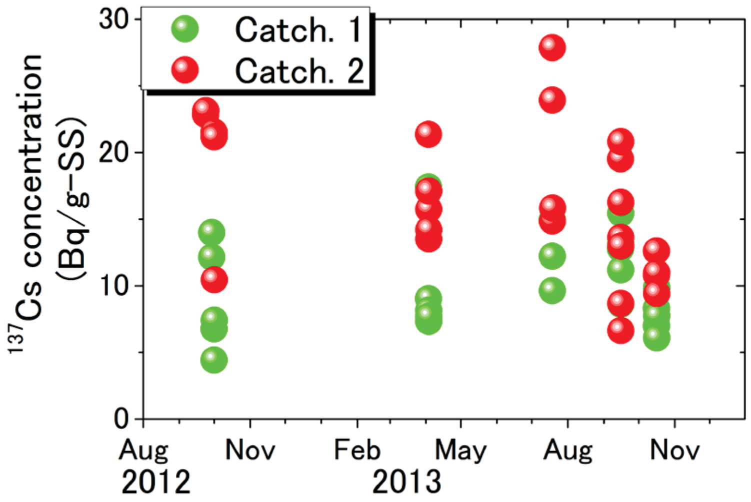
Species	Sediment load (g/m²)	^{137}Cs runoff volume (kBq/m²)	^{137}Cs runoff ratio (%)
Cedar	4.7	0.13	0.08
Red pine	28	0.25	0.16
Cypress	79	1.5	1.0
Deciduous	120	0.8	0.87

•Runoff properties vary among species
•Covering effect of understory vegetation → important factor
•Limited runoff of Cs from steep slopes

^{137}Cs runoff from forested catchment

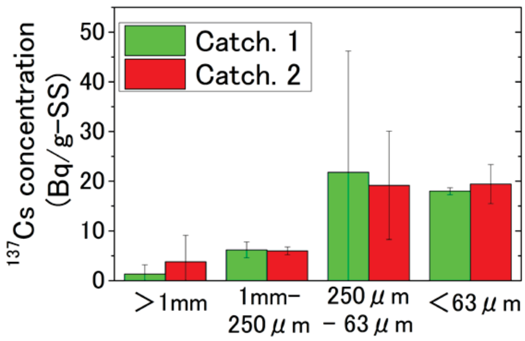
- Cs associated with SS is main component of runoff (Kd > 10^5)
- Slight decrease in Cs concentration from 2012 to 2013
- Very limited runoff of Cs even in highly contaminated region

Temporal change in conc. of sorbed ^{137}Cs on SS

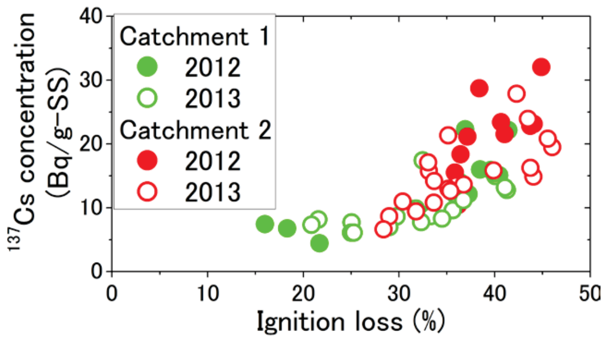


- Runoff properties corresponding well to deposition condition in forest soil
- Annual ^{137}Cs runoff ratio is 0.12 % for both catchments

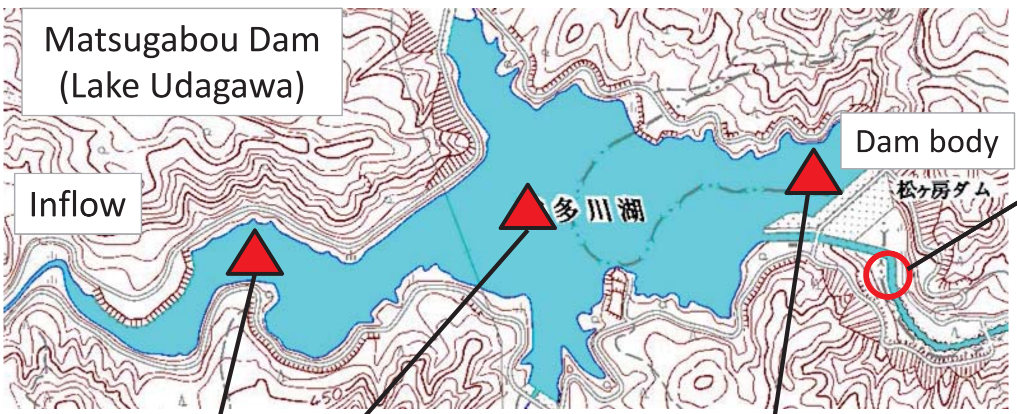
Conc. of sorbed ^{137}Cs on each faction of SS



Relationship between IL and ^{137}Cs conc.



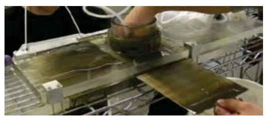
Outline of survey in dam lake



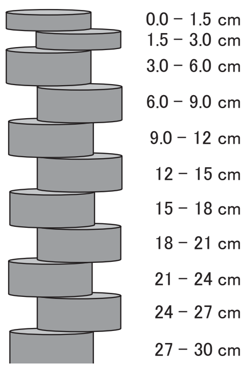
Turbidity sequential measurement & water sampling from May,2013

Vibration core sampling at the points with sandy sediment by professional diver at 2013

Using core sampler with drop-weight at the deep water point at 2012 and 2013

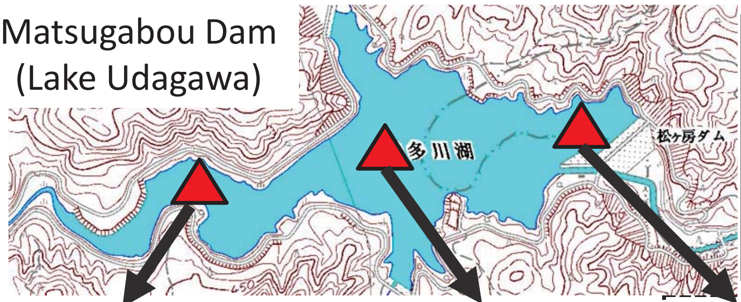


Slicing core into 1.5 to 3 cm thickness

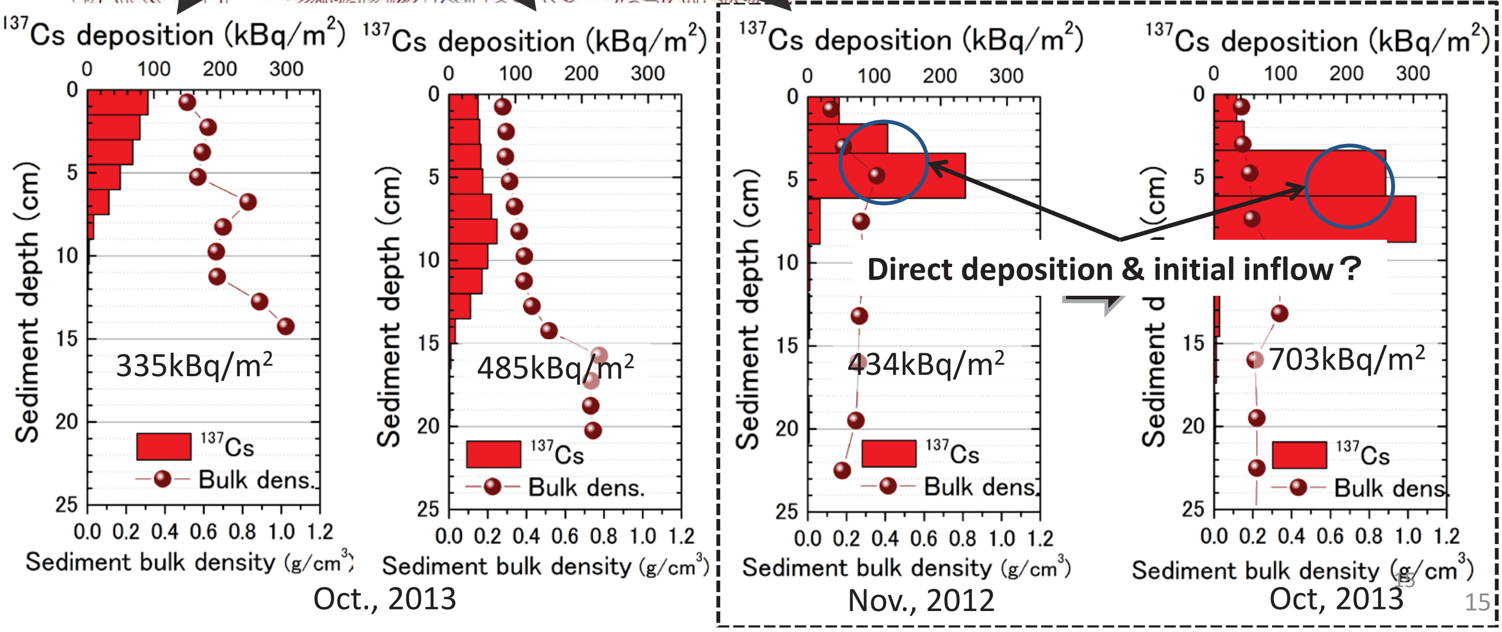


Accumulation of ^{137}Cs in sediment of dam lake

Matsugabou Dam
(Lake Udagawa)

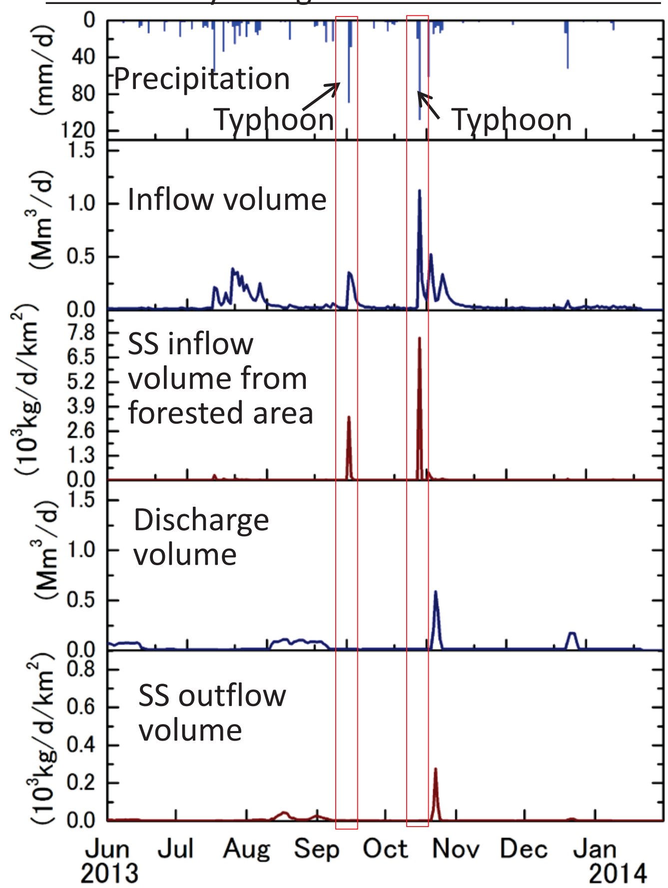


<u>Spatial distribution of Cs accumulation</u>
Behavior of inflow Cs associated with SS highly depending on flow property in the lake
<u>Behavior in highly accumulated area</u>
Current inflow sediment shielding initial Cs deposition layer

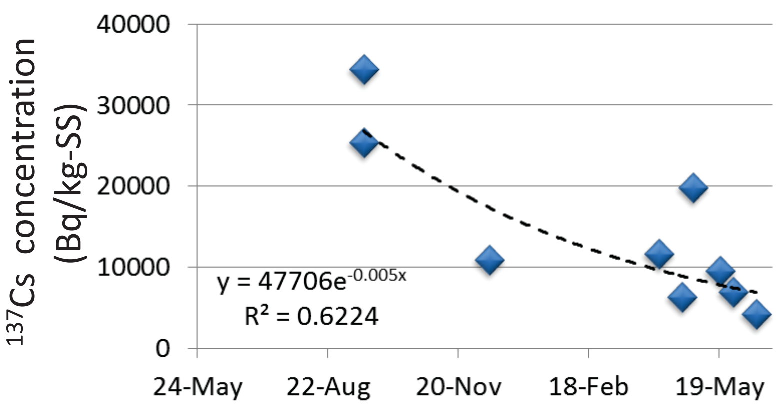


^{137}Cs retention function of dam lake

<u>Observed hydrologic data in Lake Uda area</u>



<u>Change of ^{137}Cs conc. in the dam discharge water</u>



Runoff ratio to inflow ^{137}Cs from dam lake
(2013/05/24 – 2014/1/31)

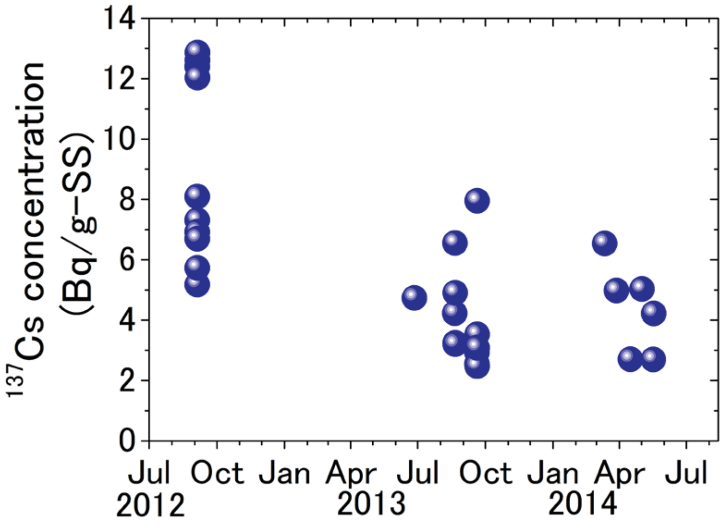
$$\frac{^{137}\text{Cs outflow} \quad \text{SS outflow} \times {}^{137}\text{Cs conc.}}{^{137}\text{Cs inflow (catchment deposition} \times \text{runoff ratio)}} =$$

$$\frac{\text{SS flux}(t) \times {}^{137}\text{Cs}(t)}{300{,}000(\text{Bq/m}^2) \times 25.6 \times 10^6(\text{m}^2) \times 0.0011} < 0.09$$

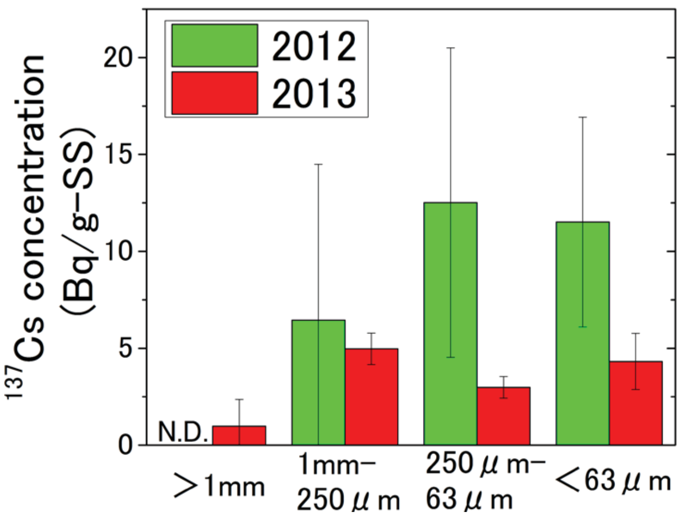
Role of dam in prevention of the proliferation of Cs to downstream area was confirmed

^{137}Cs runoff from the entire Uda River Basin

Temporal change of ^{137}Cs conc. in river water



Conc. of sorbed ^{137}Cs on each faction of SS



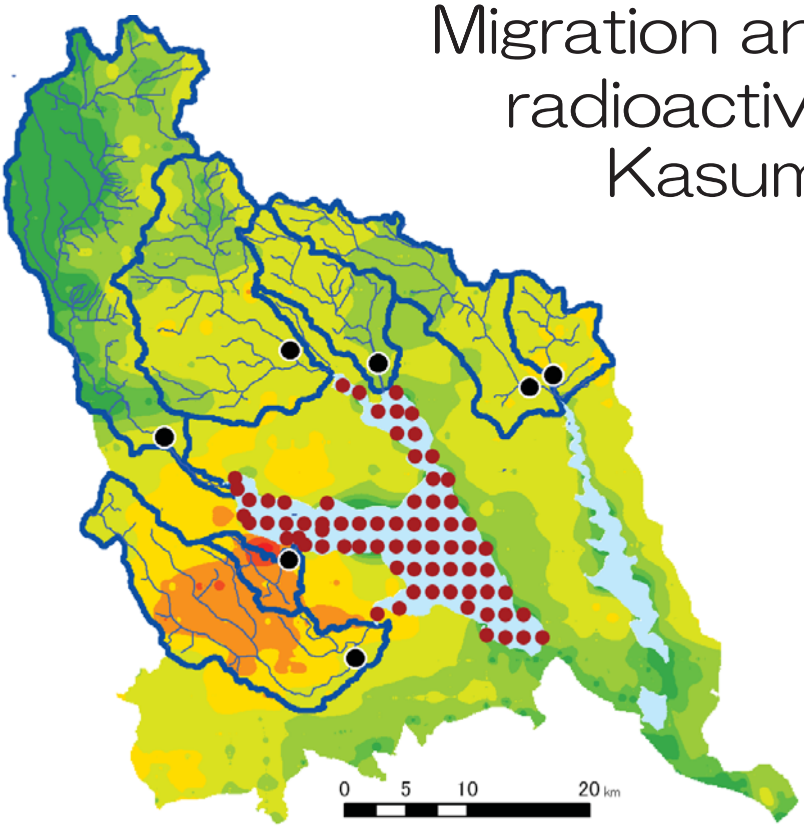
Decrease of Cs content in fine inorganic and organic matters

^{137}Cs Runoff condition from the entire basin

Total runoff amount associated with SS : 0.35kBq/m^2 (34GBq)
^{137}Cs runoff ratio : 0.17% (Jul. 2012 to Jan. 2014)

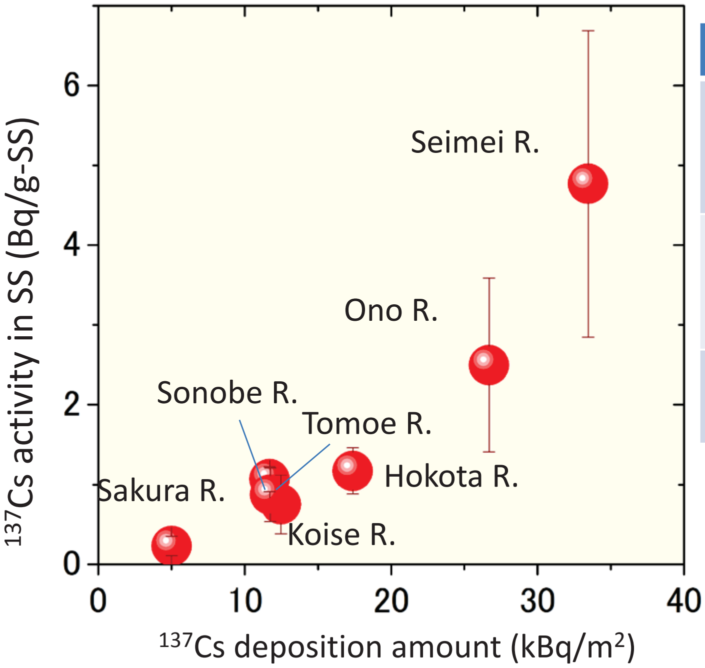
^{137}Cs runoff is currently limited from the whole basin as well as forested area.

Migration and accumulation of radioactive Cs in the Lake Kasumigaura Basin



^{137}Cs runoff from catchments of main inflow rivers to Lake Kasumigaura

Relationship between ^{137}Cs activity associated with SS and deposition amount in catchment



Estimated runoff volume of ^{137}Cs associated with SS for two years after the FDNPP accident

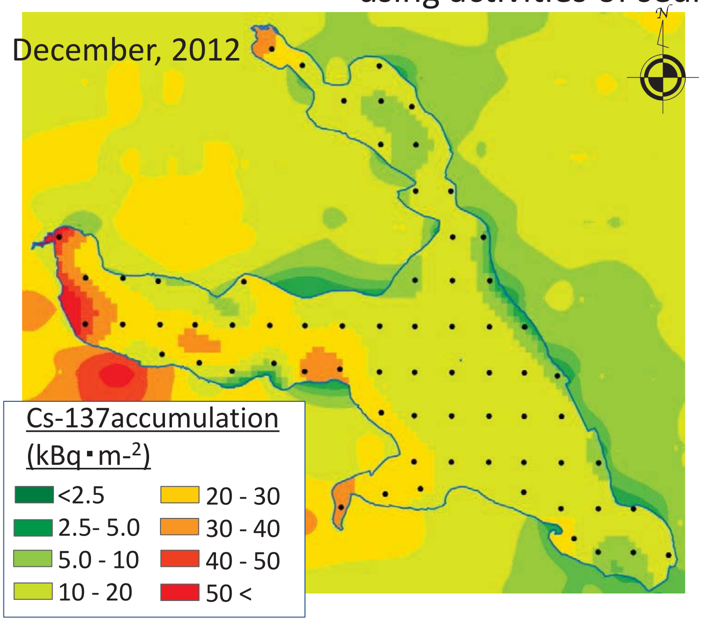
River	Sakura	Koise	Ono	Seimei	Sonobe
SS specific runoff (g/m^2)	73.8	61.6	32.2	58.3	57.2
^{137}Cs specific runoff (kBq/m^2)	0.017	0.046	0.080	0.276	0.061
^{137}Cs runoff ratio (%)	0.34	0.37	0.30	0.83	0.52

^{137}Cs slightly running off in river catchment scale!

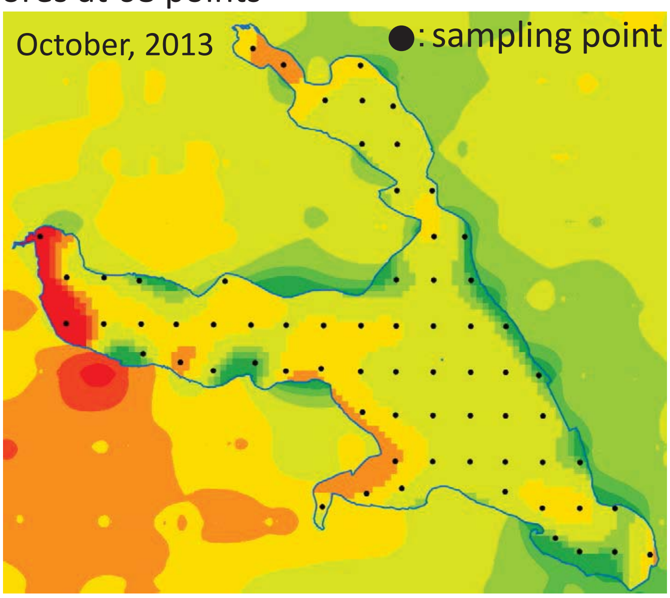
^{137}Cs activity in SS
→ depending on not conc. of SS but initial deposition amount in catchment

Change in spatial distribution of ^{137}Cs accumulation in sediment of the Lake Kasumigaura

Estimated spatial distributed map of ^{137}Cs accumulation in sediment by spline function using activities of sediment cores at 68 points



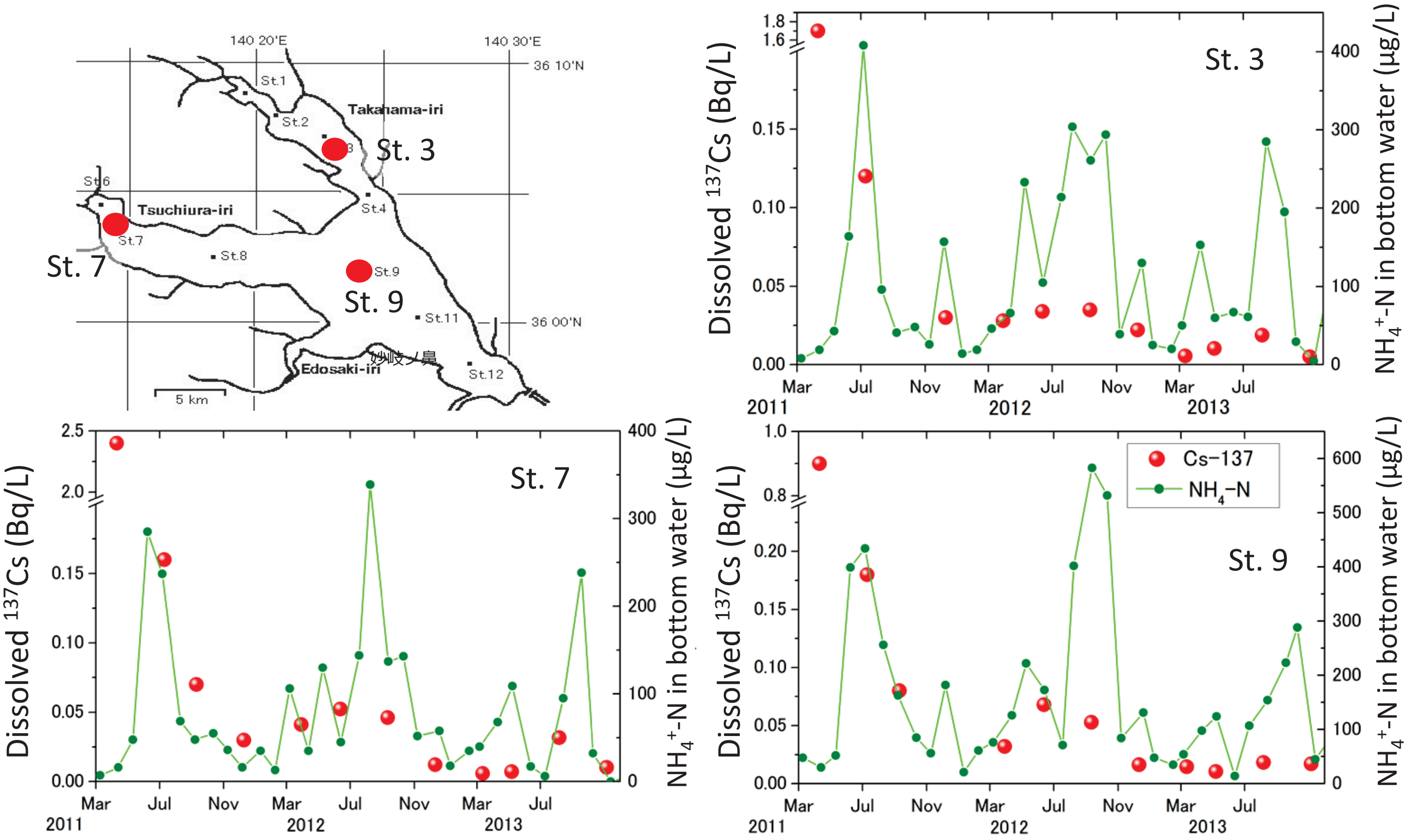
18 kBq/m² (to 15cm depth)



15 kBq/m² (to 15cm depth)
19 kBq/m² (to 25cm depth)

- Higher activities in the western side → Effect of initial direct deposition
- Locally high activities at some river mouths → Effect of inflow from the river
- Change in ^{137}Cs accumulation → Slightly increase?, Promotion of vertical mixing

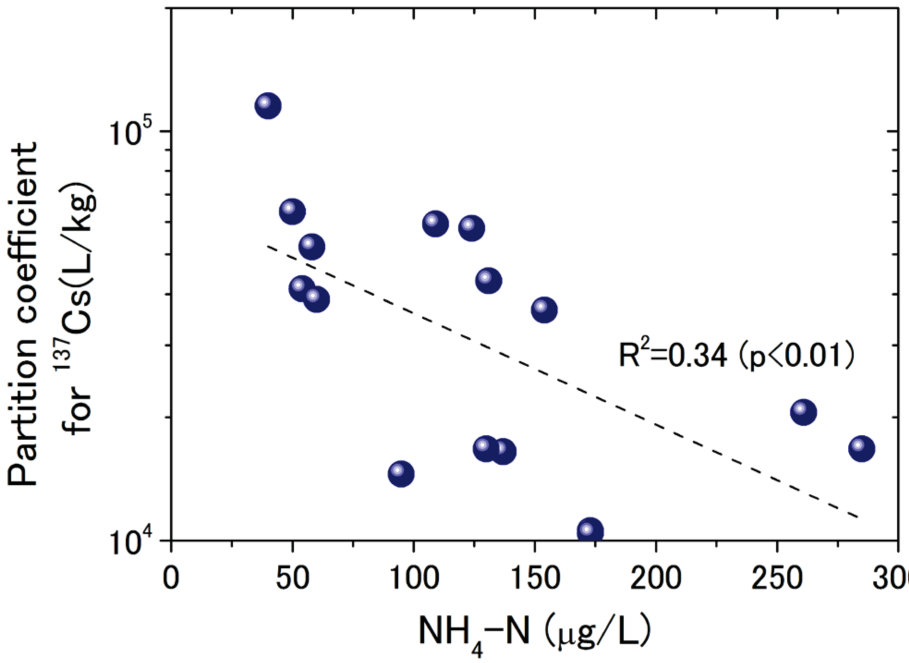
Temporal change of dissolved ^{137}Cs in the Lake Kasumigaura



Increase of Cs concentration In summer → effect of NH_4^+ production in sediment ?

Effect of sediment environment on production of dissolved Cs

Relation of NH_4^+ concentration in the lake bottom water to distribution condition of ^{137}Cs between sediment surface layer and lake water



- Marked growth and decomposition of algae

↓

- Generation of reduction condition and NH_4^+ in lake sediment

↓

- Promotion of Cs solubilization from solid phase

Concern about the effect on Cs transition to aquatic ecosystem and agricultural food

Same phenomena possibly occurring in eutrophied lakes and ponds in Fukushima prefecture

Aim and monitoring target

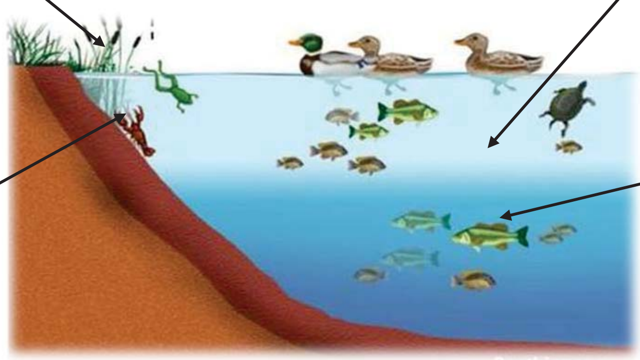
From a viewpoint of ecological and biological theory,

Understanding accumulation and behavior of radiocesium in freshwater biota, **identifying the factors** determining these processes, and **predicting the decay rate and process**.

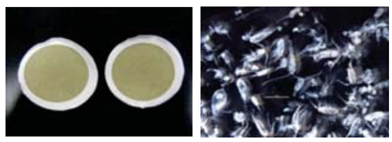
Emergent plants

Benthic macro-invertebrates

Lake Kasumigaura



Plankton

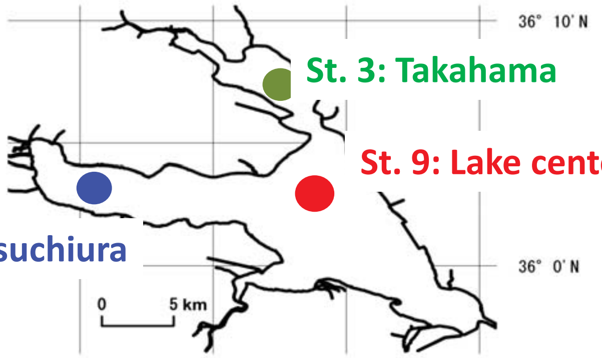


Fish

Started in July 2011

Plankton survey and sampling

- Site: **three sites** in Lake Kasumigaura
- Frequency: every **3 months**
- Sampling and treatment

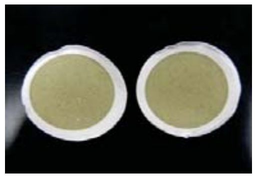


Lake water

- Filtration with a large-mesh sized plankton nets (25 t) → **>200μm**
- Filtration with a small-mesh sized plankton nets (25 t) → **>40μm**
- Filtration using GF/C in labs (20 t) → **SS (>1.2μm)**

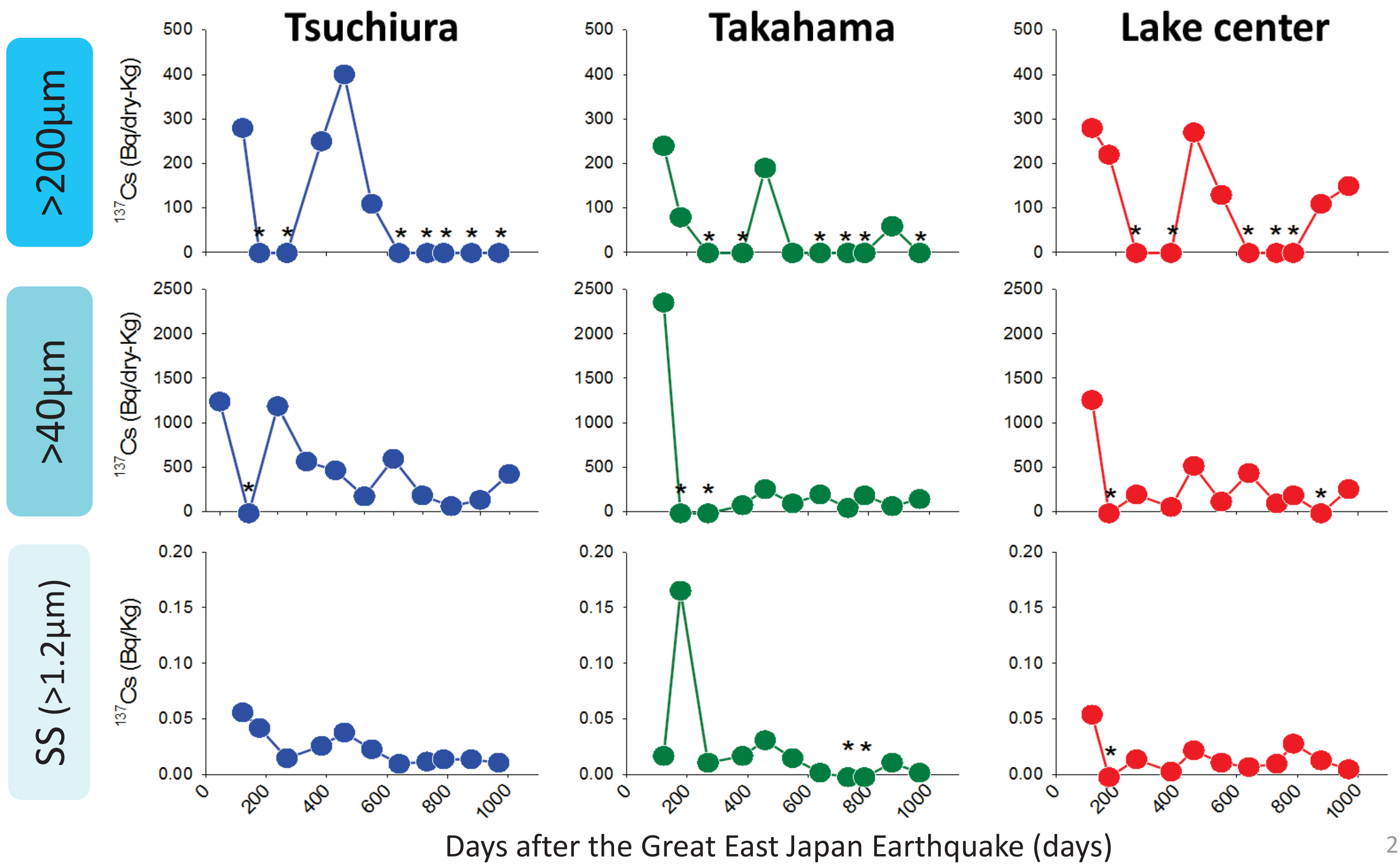
Mainly zooplankton

Mainly zoo- and phyto-plantkon

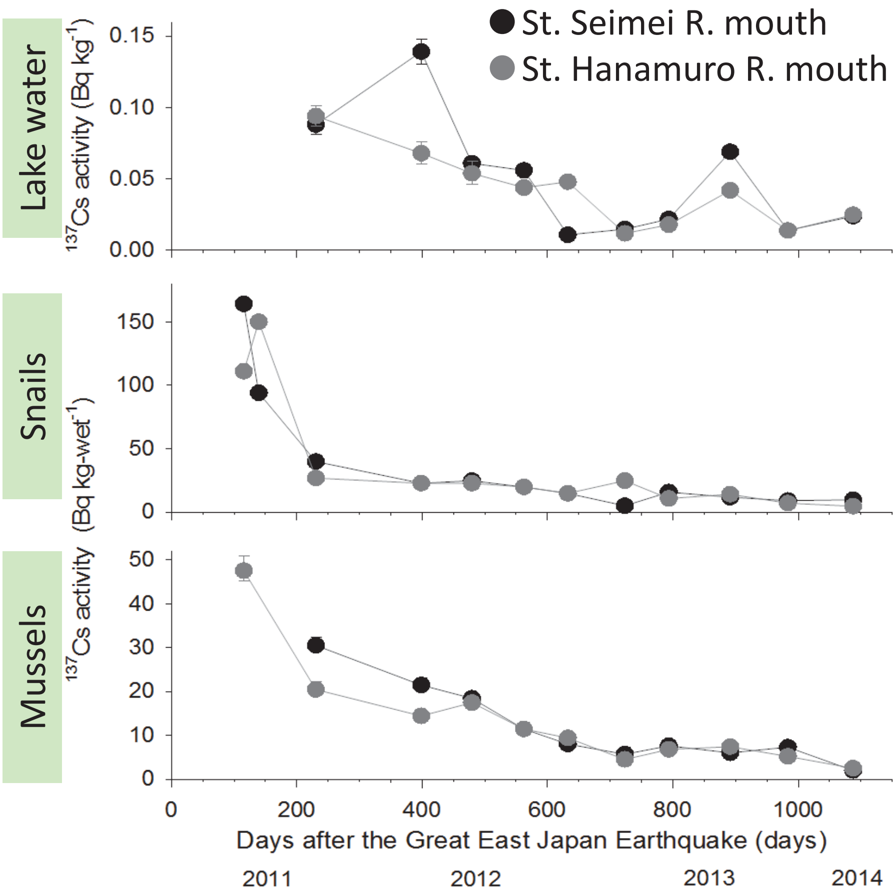


Suspended solids

Trends in plankton ^{137}Cs conc.



Concentration factors and ecological half-lives of Mollusks



Concentration factor

Snail ＞ Mussel

Snail: 547～593

Mussel: 282～338

→Difference in functional group

Ecological half-lives

Snail: 365～578 days

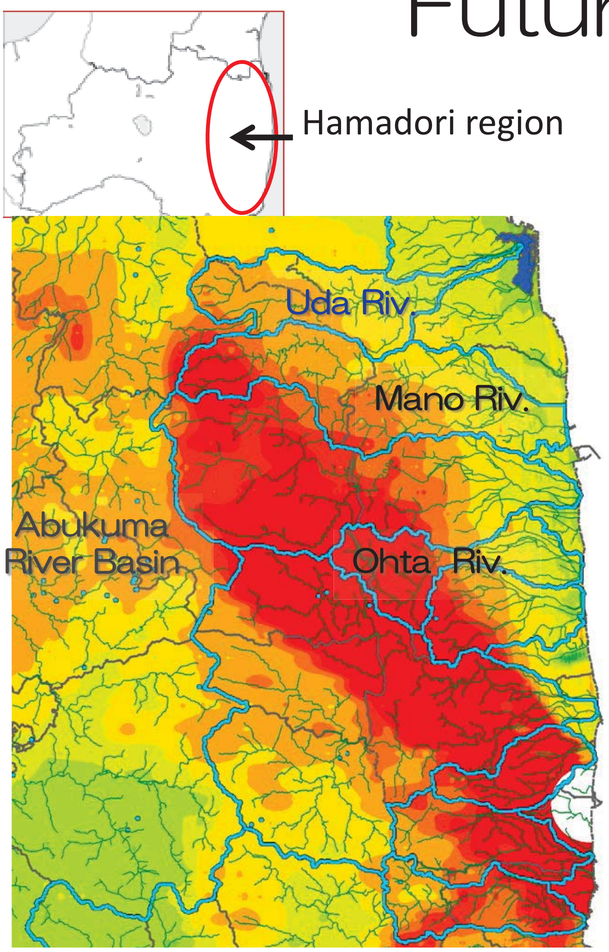
Mussel: 267～365 days

Much longer than "biological" half lives, which are estimated to be 3 to 38 days.

↓

Dietary uptake dominates the total uptake of Cs, and Cs has continued to accumulate in snails and mussels.

Future perspective



- Expand our research target area to the main rivers' basins in the north Hamadori region
- Evaluate role and effect of dam lake on Cs behavior in river basin scale
  → Cooperation with JAEA in the Ohta River
- Investigate and analyze the transfer properties of ^{137}Cs in aquatic ecosystems
  → Cooperation with Moe in the Mano River
- Develop and apply strategic environmental assessment (SEA) method for a project conducted in a catchment scale to reduce radiation exposure
  → Cooperation with JAEA, Fukushima Pref., and MOE

Development and application of SEA method for a project in a catchment scale to reduce radiation exposure

Developing SEA method of PDCA type toward reduction of exposure and safe return of refugees
Proposed as inter-organ and cross-cutting project in Center for Fukushima Environmental Creation

	Plan	Understanding of actual condition	Decontam. technique	Effect on exposure reduction	Prediction of Cs behavior	Ecosystem impact & Landscape change	Disposal of decontam. waste	Comprehensive evaluation	Consensus-building method with resident participation
SEA procedure	M, F	F, J	J	J, N	J, N	N	J,N	N	F, N
Planning development	●	○	○						
Prior assessment				●	●	●	●	●	○
Consensus-building with residents	●								○
Operation	●								
Ex-post assessment				●	●	●	●	●	○
Comprehensive evaluation				○	○	○	○	●	○
Dialogue with residents	●								○
Additional operation review	●								

M: Ministry of Environment, F: Fukushima Pref., J: JAEA, N: NIES

Transmission and return of research outcome to the people of Fukushima Prefecture

- Holding of public symposium and delivery course in related municipalities as a venue for two-way dialogue

Symposium in Kohriyama city on Mar. 2013

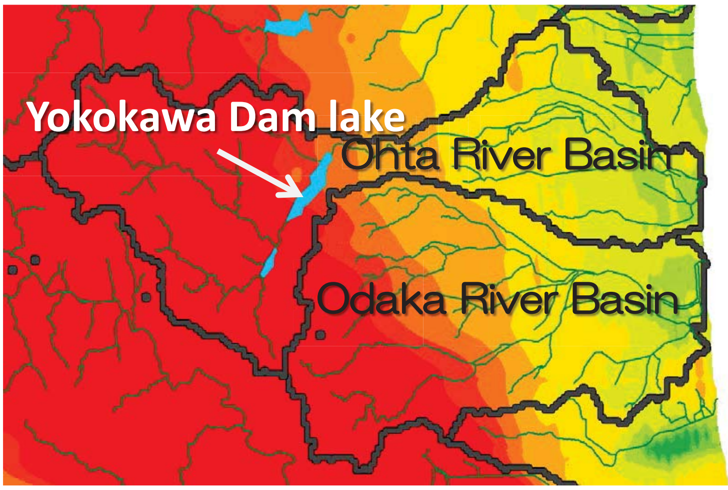
- Contribution to planning and implementation of policy measures by Fukushima prefecture and municipal government
  → provision of scientific knowledge and participation in review committee

- Active involvement in regional decontamination operation as a main member of Center for Fukushima Environmental Creation

Thank you for your attention!

Appendix:

Evaluation of role and effect of dam lake on Cs behavior in river basin scale



- Cooperative survey with JAEA

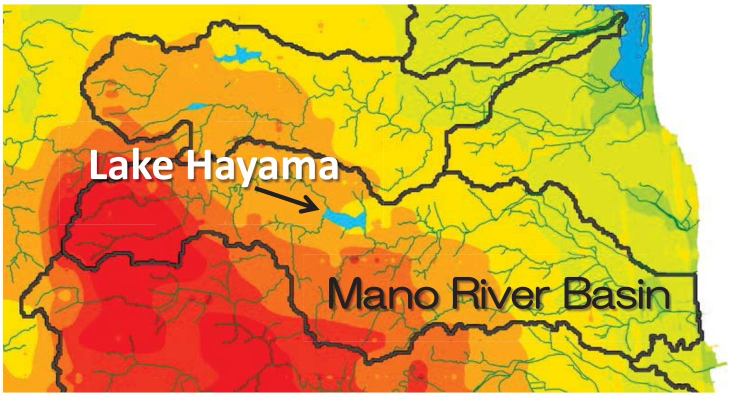
・NIES：
→Cs budget in the dam lake
→Cs flux for varied absorbed form

・JAEA
→Cs behavior in the dam lake
→Cs deposition in river bank and estuary

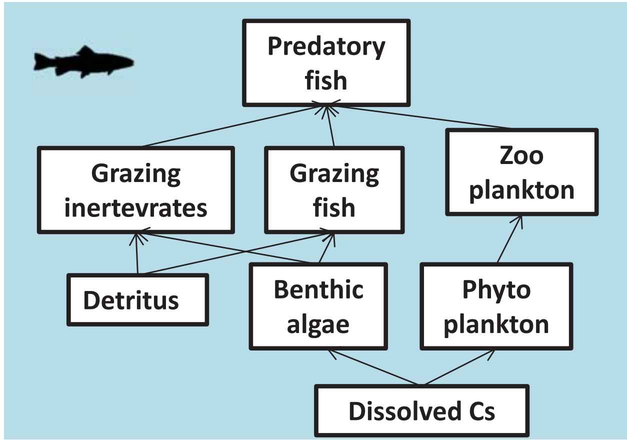
- Role and effect of dam on Cs migration and accumulation in the lower reach (living area) by comparing with results in the basin without river dam (Odaka River)
- Role of dam on production of bioavailable Cs
  →Effect on Cs migration into paddy rice
  →Effect on Cs transfer in aquatic ecosystems

Appendix: Clarification of Cs transfer properties through food webs

Aquatic organism monitoring in rivers and lakes with a central focus on Mano River



Food web in terrestrial water



Qualitative estimation of food webs using C and N nitrogen stable isotope ratio analyses

- ✓ Estimation of Cs transfer between compartments
- ✓ Estimation of Cs uptake process through each food web （e.g. grazing food chain vs detritus food chain？）
- ✓ Development of dynamic prediction model → evaluation of changes in contamination level