Impacts of climate warming on the life history of ayu *Plecoglossus altivelis* in the Nagara River system

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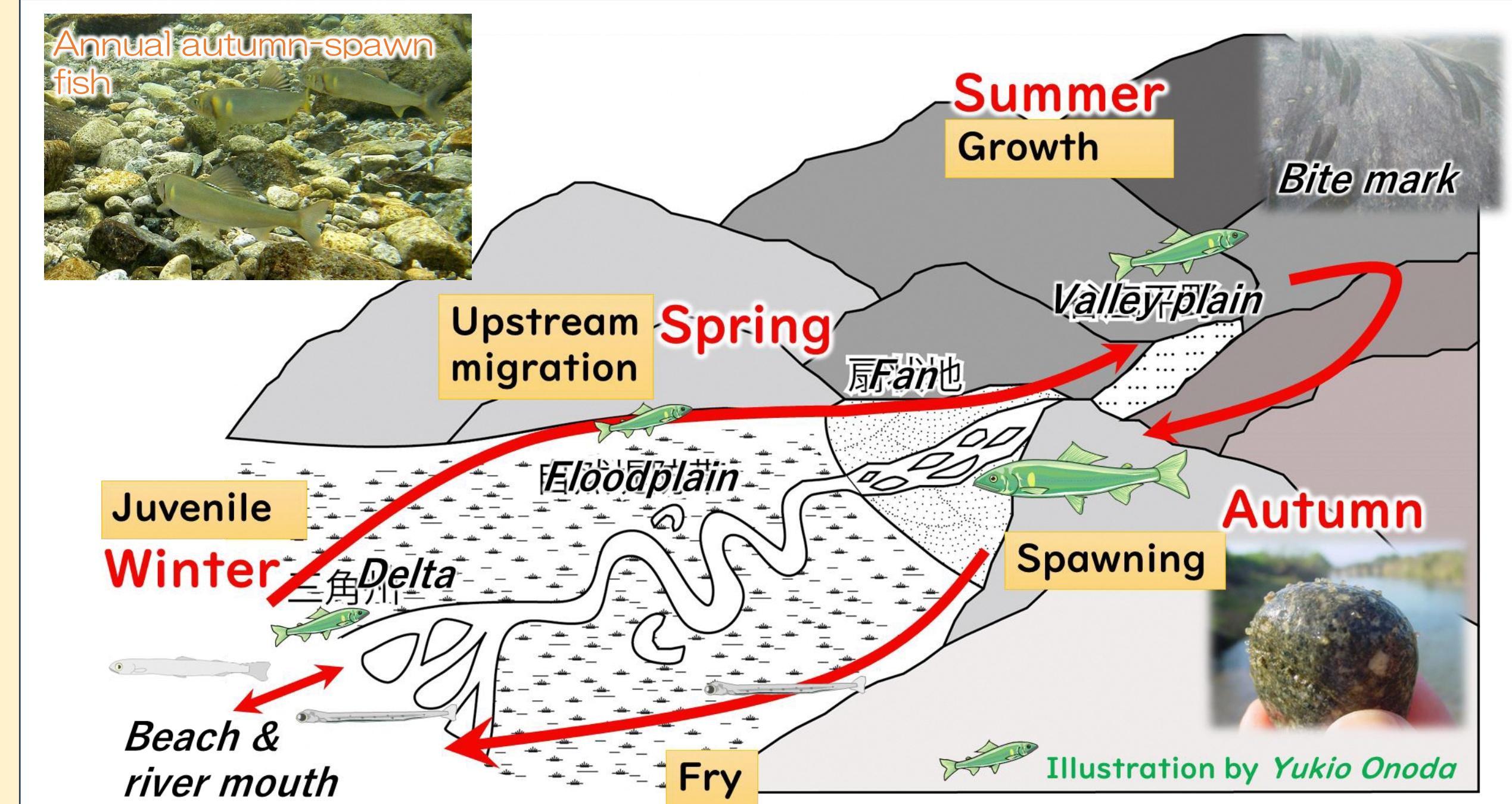
Backgroud :

◆ **Ayu** (sweet fish)
- ✓ GIAHS "ayu of the <u>Nagara River System</u>"
- ✓ Fisheries resources in Japanese rivers
- ✓ Forming regional industry and culture

◆ **Climate warming**
- ✓ Rising 1.35 ℃ of air temperature and 1.05 ℃ of river water temperature in 100 years in Japan
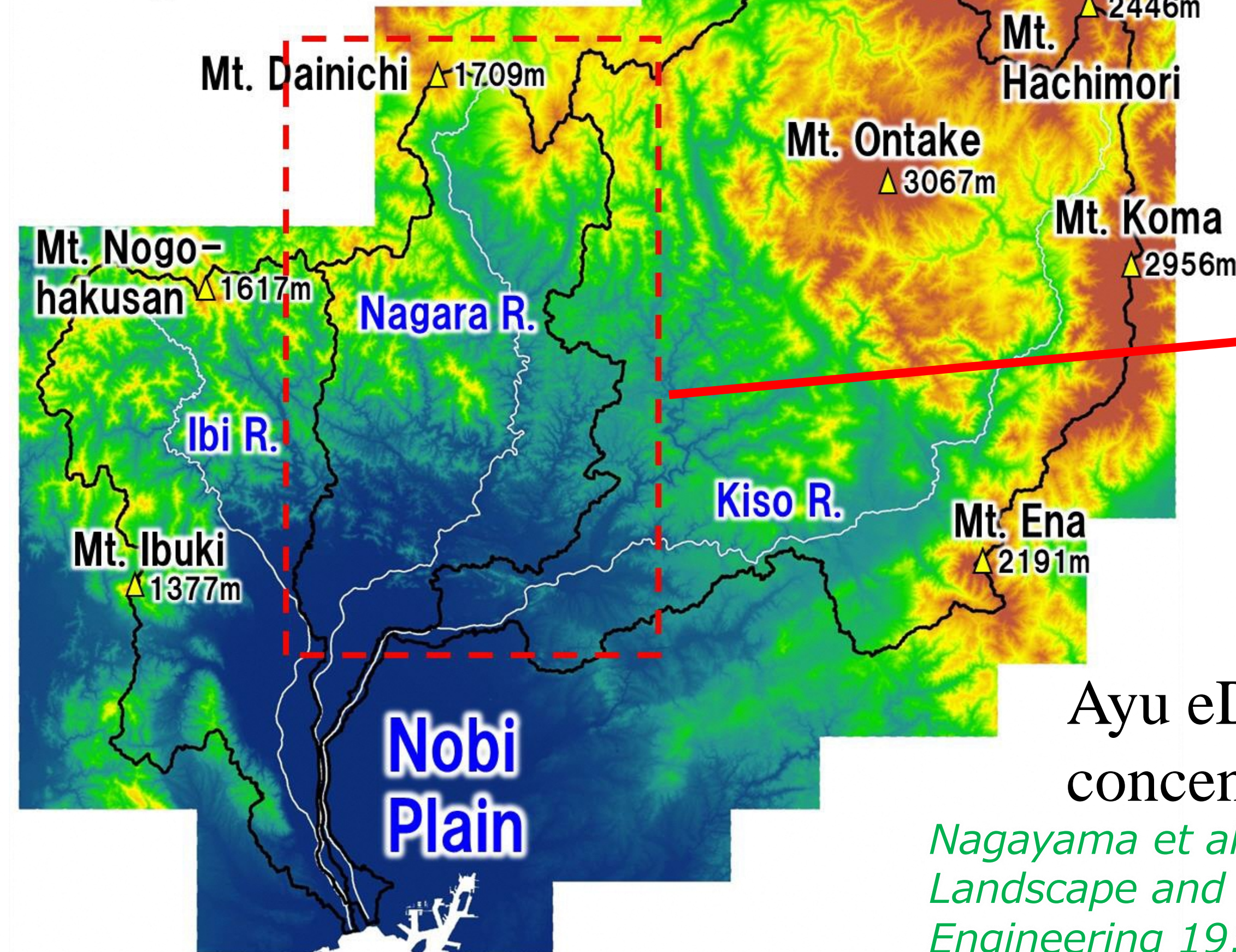- ✓ Rising 1.8 ℃ of air temperature in 100 years in Gifu, Japan

Life history of ayu

Annual autumn-spawn fish
Summer — Growth — Bite mark — Valley plain
Upstream migration — Spring — Fan 扇状地
Juvenile — Winter — Floodplain — Autumn — Spawning
Delta 三角州
Beach & river mouth — Fry
Illustration by *Yukio Onoda*
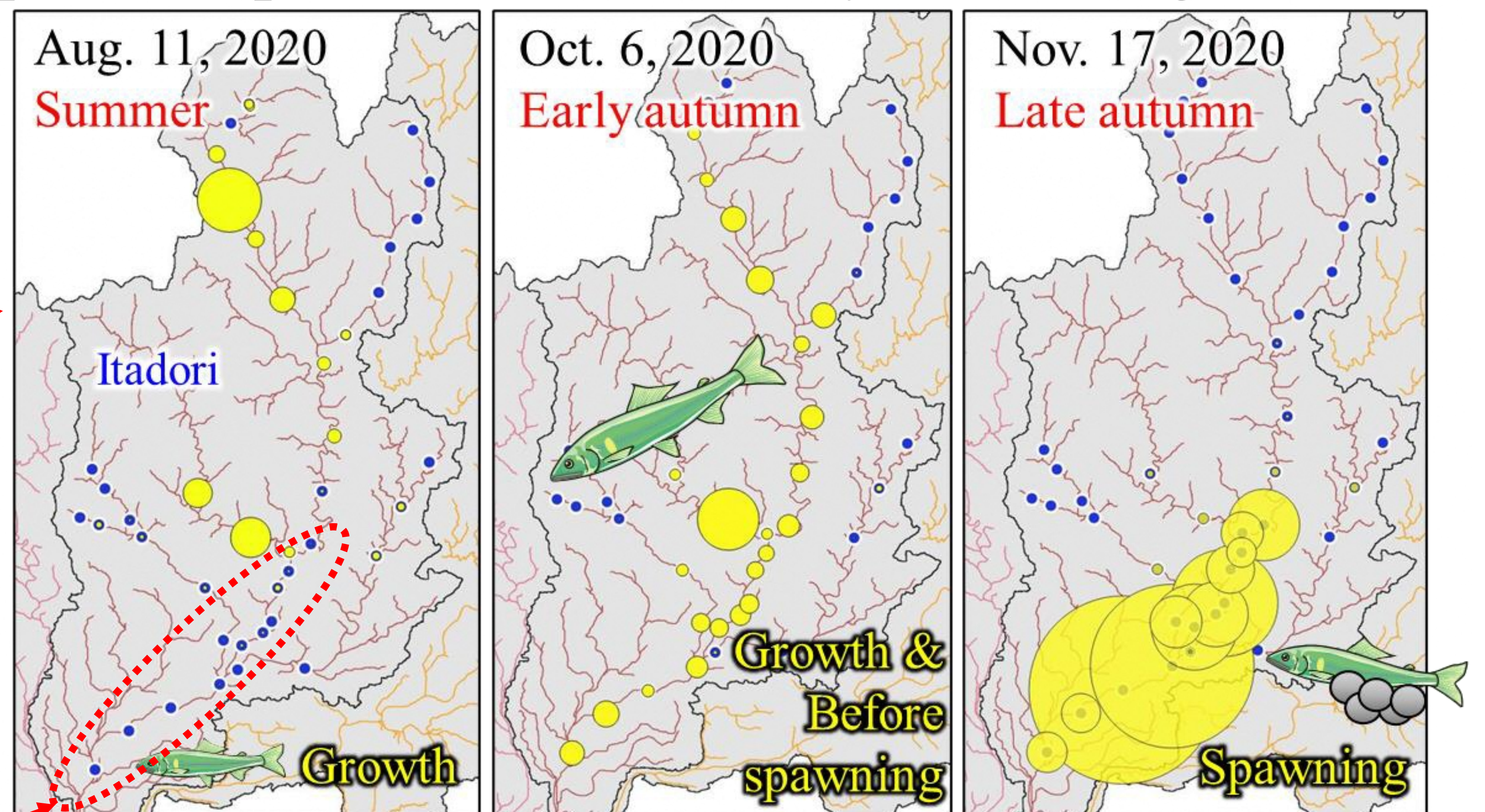
In the Nagara River, …
- ➢ Peak of upstream migration in Apr-May (avg. 5 million fish/year, but large fluctuation)
- ➢ Over 140 km of upstream migration from the river mouth
- ➢ About 4 million fish stock/year
- ➢ Widespread in summer
- ➢ Downstream spawning migration toward fan (40-55 km) in autumn
- ➢ Peak of spawning after mid/late Oct. in recent years
- ➢ Peak of hatch after early Nov.

Impacts of climate warming on ayu in the Nagara River based on our recent studies ①〜③
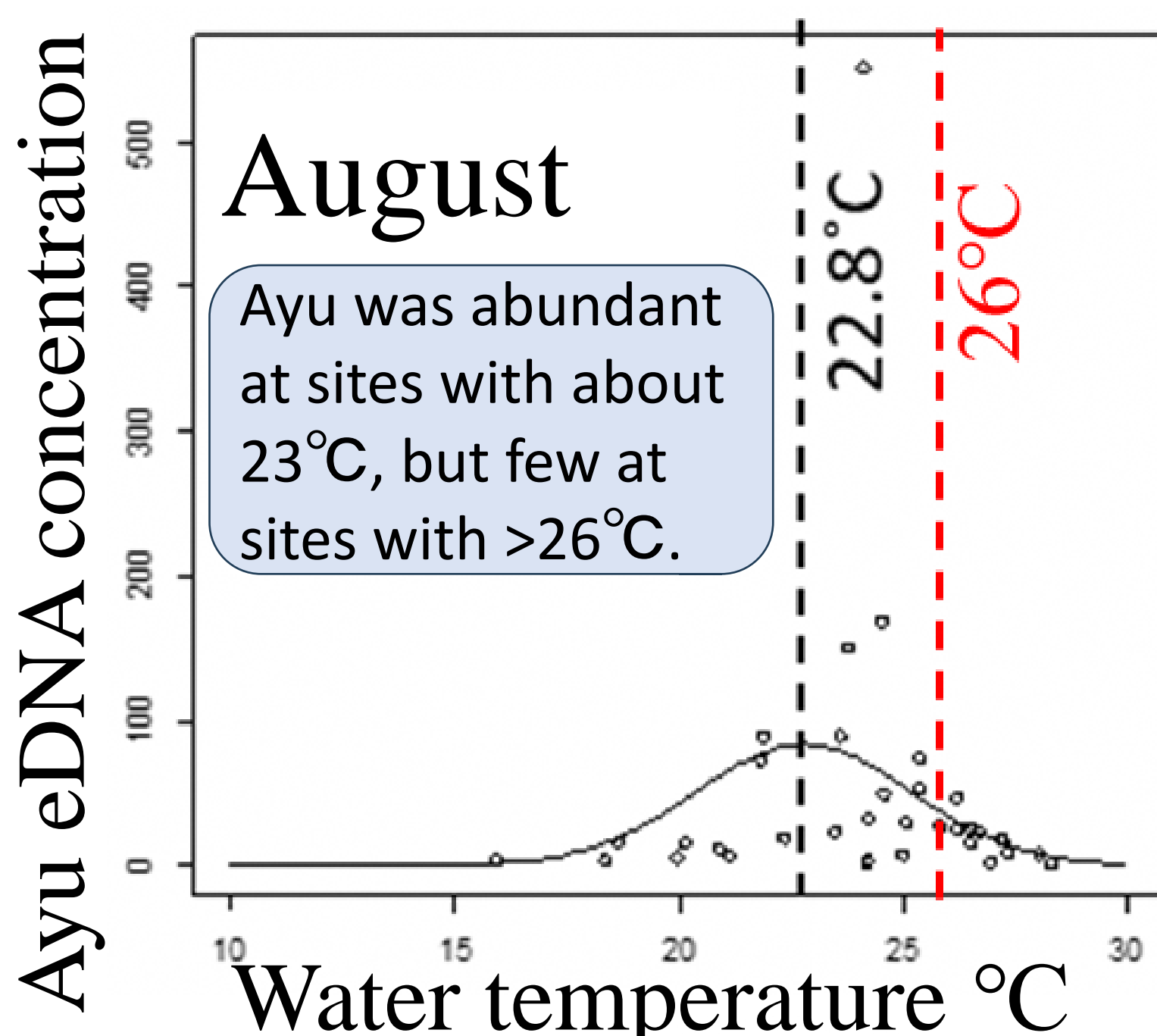
Three river basins flowing through the Nobi Plain

Mt. Norikura △3026m, △2446m
Mt. Hachimori
Mt. Dainichi △1709m
Mt. Ontake △3067m
Mt. Nogo-hakusan △1617m
Nagara R.
Mt. Koma △2956m
Ibi R.
Kiso R.
Mt. Ena △2191m
Mt. Ibuki △1377m
Nobi Plain

Spatio-temporal distribution of ayu in the Nagara River

Aug. 11, 2020 — Summer — Itadori — Growth
Oct. 6, 2020 — Early autumn — Growth & Before spawning
Nov. 17, 2020 — Late autumn — Spawning

Ayu eDNA concentrations
Nagayama et al. (2023) Landscape and Ecological Engineering 19: 21-31

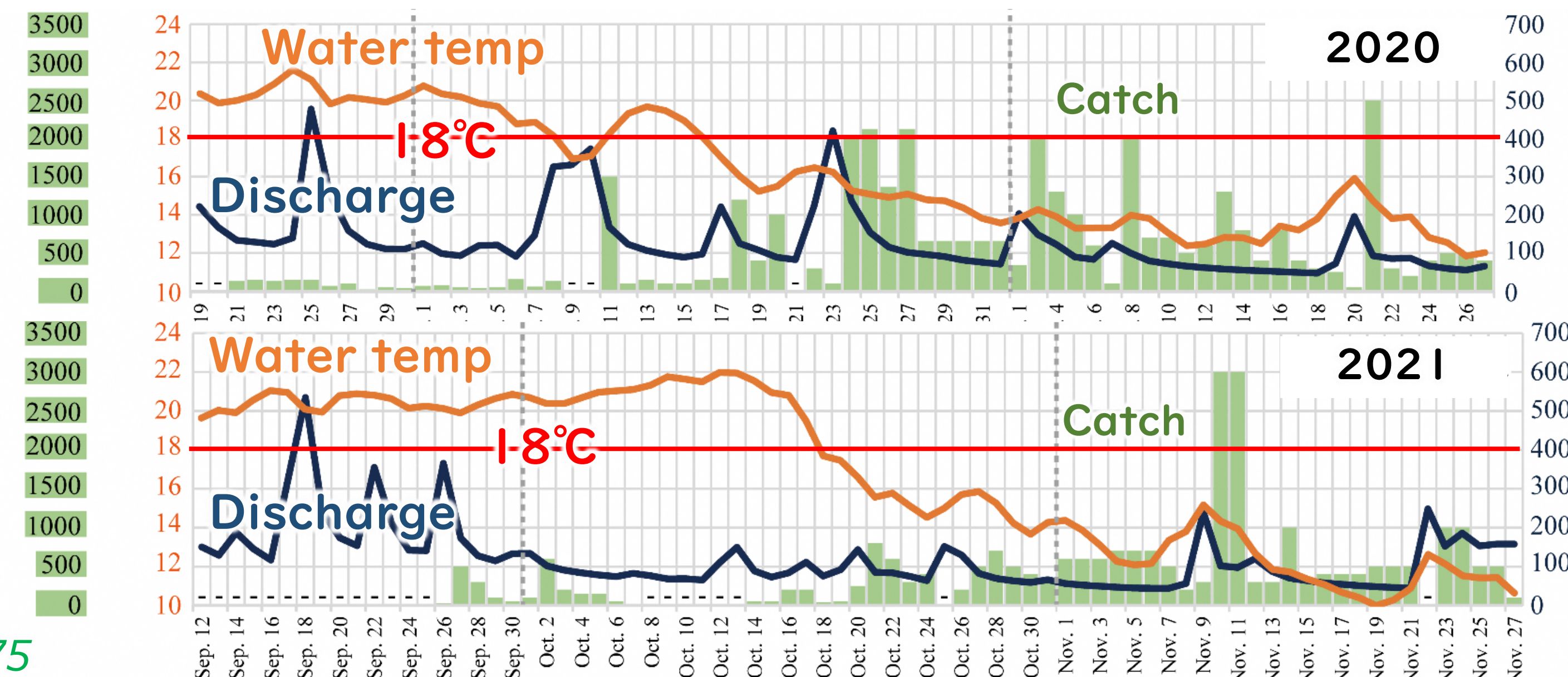### ①Limited Summer Distributions

Ayu disappeared from the downstream reach of the Nagra River where the mean daily water temperature **exceeded 26 ℃**.

Tributaries and upper main reaches with low water temperatures provided **summer refuge habitat** under climate warming trend.

August
Ayu was abundant at sites with about 23℃, but few at sites with >26℃.
22.8℃
26℃
Ayu eDNA concentration
Water temperature ℃

②Delayed Autumn Spawning Migration

The downstream spawning migration of ayu was triggered by two factors: mean daily water temperature **below 18 ℃** and **water discharge increase**. The downstream migration have been delayed by about one month over the last half century due to rising water temperature.

Sebari-ami fishing
Catch

Nagayama et al. (2023) Fisheries Science 89: 463-475

Water temp — 18℃ — Discharge — Catch — 2020
Water temp — 18℃ — Discharge — Catch — 2021

③Delayed Hatching in late autumn

The peak hatch dates for ayu fry have been gradually delayed over the last 30 years. The first peak has become smaller.

Oct. 1 — Nov. 1 — Dec. 1 — Peak of fry hatch
1993 — Late Sep. & Late Oct.
2017 — Mid Oct. & Early Dec.
2023 — Early Nov. & Early Dec.
Fry hatch amount