What Have You Been Eating?

Materials

For the leader:

Whiteboard

Markers (different colors)

For the activity:

Copies of diet graphs

Copies of student handouts

Overview

Scientists studying ecology ask broad questions about how the patterns and behaviors of animals change through space and time and the environmental factors that influence the distribution and abundance of individuals. Therefore for fish ecologists, a major question when understanding a population of fish is: what do they eat. Understanding what a fish eats can provide a lot of information about how that fish interacts with its environment. If it only eats things that live on the bottom of the ocean, then we know that fish spends a lot of time near the bottom of the ocean. Scientists also use information from diet studies to understand where different species of fish fit into the food web of an ecosystem, and thus what species need to be present for that fish to survive.

Answers to questions about diet of individual fish, as well as for the entire population, have important implications for understanding marine food webs, managing fisheries, and protecting marine and aquatic systems. Management and conservation decisions are made using the "best available science," which for fish includes knowledge of how a population is interconnected with other organisms within the ecosystem and what factors effect these interconnections. Therefore, by understanding diet of individuals we can better understand patterns of the population as a whole and thus make better management and conservation choices.

There are multiple ways to study the diets of fish and each carry their own benefits and disadvantages. Diet or gut content analyses involve pumping a fish's stomach (gut lavage) or dissection. The benefits are that you get a clear indication of what the fish was eating, often to species level. However, you are only learning what the fish has consumed recently (within the last day often) and hard parts of prey items are more difficult to digest so they are often overrepresented in the data. Chemical techniques using analyses of tissue samples, such as stable isotopes or fatty acids, provide a better long-term (often 6 months) picture of what the fish has been eating. However, you are not able to learn the specific prey items but rather the source of carbon of the food and what trophic level the fish is eating at.

Fish can be classified broadly by their feeding habits as detritivores (eat decomposing plant and animal parts and organic fecal matter), herbivores (eat plants and plant-like organisms), carnivores (eat other animals), piscivores (eat fish), and omnivores (eat plants, plant-like organisms, and animals). Depending on the feeding habits of the fish, they are obtaining their carbon from different sources (e.g., an herbivore obtains carbon directly from a plant while a piscivore obtains carbon from a fish that obtained it from another source further back in the food web). Scientists have discovered that by measuring the carbon in the tissue of a fish you can determine the source of the carbon and thus get an estimate of what kind of feeding habits that fish exhibits.

Additionally, as you move up a food web, away from the plant or plant-like source of carbon, the trophic level increases. Scientists have determined that by measuring the nitrogen in the tissue of fish you can assign the fish to a specific trophic level. Trophic levels typically are thought of as:

- Level 1: Plants and algae make their own food and are called primary producers.

- Level 2: Herbivores eat plants and are called primary consumers.
- Level 3: Carnivores which eat herbivores are called secondary consumers.
- Level 4: Carnivores which eat other carnivores are called tertiary consumers.
- Level 5: Apex predators which have no predators are at the top of the food chain.

However, in studies using nitrogen the scale varies from this model but the principle is the same, the higher the number the higher the trophic level. In nitrogen studies a complete trophic level is roughly 3.4 units.

Isotopes are naturally occurring or man-made variations of an element. All isotopes of the element have the same number of protons (as that identifies the element), but the number of neutrons varies among isotopes. Therefore, isotopes with higher numbers of neutrons have a higher mass number (as that is calculated from the number of protons plus the number of neutrons) and thus mass. Scientists can look at the ratio of different isotopes of the same element in a given structure to gain a better understanding of such things like when that structure was built (e.g., carbon dating) or what the organism eats (e.g., muscle tissue analyses). Stable isotopes are isotopes that are not radioactive, meaning they do not decay spontaneously over time but rather forever keep the same number of neutrons. In many diet studies, scientists compare δ^{13} C to δ^{12} C and δ^{15} N to δ^{14} N. The comparisons in this study are presented as δ^{13} C and δ^{15} N values.

Motivating Questions: How do scientists determine the diet of a fish and whether the diet changes over time?

Take Home Message

Students learn how to determine the diet of fish based upon stable isotope data (carbon and nitrogen) and how that diet may change over time.

Engage: Lead the students in a discussion about what they know about diet studies, what diet studies tell us, and about stable isotopes.	10 minutes
Explore: Lead the students in an investigation of the stable isotope data to determine the fish diet and then to determine if the diet changes with age.	25 minutes
Make Sense: Students share their observations, ask questions, and discuss what they can learn from the diet results.	10 minutes
Total:	**45 minutes**

Audience

Middle and high school students (6th-12th grade).

New Jersey Core Curriculum Content Standards - Science

Grade	Content Statement	CPI#
6	The number of organisms and populations an ecosystem can support depends on the biotic resources available and on abiotic factors.	5.3.6.C.2
6 / 8	All animals, including humans, are consumers that meet their energy needs by eating other organisms of their products.	5.3.6.B.2 / 5.3.8.B.2
8	Symbiotic interactions among organisms of different species can be classified as: producer/consumer, predator/prey, parasite/host, scavenger/prey, decomposer/prey.	5.3.8.C.1
8	Food is broken down to provide energy for work that cells do, and is a source of the molecular building blocks from which needed materials are assembled.	5.3.8.B.1
8	Mathematics and technology are used to gather, analyze, and communicate results.	5.1.8.B.2

8	Evidence is generated and evaluated as part of building and refining models and explanations.	5.1.8.B.1
8	Scientific reasoning is used to support scientific conclusions.	5.1.8.B.4
8 / 12	Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.	5.1.8.B.1 / 5.1.12.B.1
12	Mathematical tools and technology are used to gather, analyze, and communicate results	5.1.12.B.2
12	Empirical evidence is used to construct and defend arguments.	5.1.12.B.3
12	Scientific reasoning is used to evaluate and interpret data patterns and scientific conclusions.	5.1.12.B.4
12	As matter cycles and energy flows through different levels of organization within living systems (cells, organs, organisms, communities), and between living systems and the physical environment, chemical elements are recombined into different products.	5.3.12.B.1
12	Biological communities in ecosystems are based on stable interrelationships and interdependence of organisms.	5.3.12.C.1

Preparation (20 minutes)

1. Write the motivating questions on the board:

   How do scientists determine the diet of a fish and whether the diet changes over time?

2. Make copies of the student worksheet for each student (last two pages of this document).
3. Make a print out of the stable isotope graph with just the zooplankton and snails data to review with the class, or project the graph.
4. Make copies of the fish stable isotope graphs.

Engage (10 minutes)

1. Lead the students in a discussion about what they know about diets of fish and what diet studies tell us.

Q. What do you know about the diets of fish?

Q. What information can scientists get about a fish, the food web, and the ecosystem from looking at the diets of a fish?

Q. How would scientists learn about the diet of a fish?

2. After a few minutes, ask the students how scientists learn about the diet if a fish. What are methods that scientists can use to study a fish's diet? Be accepting of all answers, this is just a brainstorming session. If the students get stuck, offer them some ideas: stomach content analysis (make them throw up their food or dissect the stomach), excrement analysis (look at scat), or tissue sampling (fatty acids or stable isotopes).
3. Finally, lead the students in a discussion about stable isotopes.

Q. What are stable isotopes?

Q. What can scientists learn about the diet of a fish using stable isotopes rather than stomach content analysis?

Explore (25 minutes)

1. After a few minutes, explain to the students that they will be taking a closer look at the diet of multiple fish species in a lake in Mongolia to determine what the fish eat and what that can tell

us about the ecosystem and food web. Previous gut content analyses demonstrated that the fish were eating zooplankton and benthic snails, so those are the prey items we will focus on.

2. Talk to the students about looking at stable isotope graphs. Remind them that the data is from the muscle tissue of the fish. Help the students orient to the set-up of the graph:
    a. The x-axis is the carbon source in the diet, the amount of δ^{13} C in the muscle tissue.
    b. The y-axis is the trophic level of the fish, the amount of δ^{15} N in the muscle tissue.
    c. Each sample of tissue will have both a δ^{13} C and a δ^{15} N value, and thus will be plotted as a point on the graph.
    d. For the fish data, explain to the students that the mean δ^{13} C and δ^{15} N values were calculated for each species over the three years the scientists sampled the lake (this is called a grand mean). A circle on the graph represents the grand mean.
    e. Also for the fish data, the boxes may confuse the students. Because we are looking at a mean and there is natural variation in the data, we have drawn a box around the grand mean that indicates a distance away from the mean of two times the standard deviation. The standard deviation shows how much variation or "dispersion" exists in the actual data points from the mean. A low standard deviation means that the data points tend to be very close to the mean, whereas high standard deviation means that the data points are spread out over a large range of values. The closer the data points are to the mean the more confident you can be in making conclusions from your results.
3. As a class, review the results for the prey items (zooplankton and snails). Ask the students what patterns they see in the stable isotope data for the prey items. Make sure your students observe that the benthic (snails) and pelagic (zooplankton) prey items have very different carbon signals. Ask the students how this will help us understand what the fish are eating. (If the fish separate out clearly along the x-axis to clump around either the zooplankton or snails then that will clearly indicate what the fish are eating.)
4. Each group will be assigned a species of fish to investigate the diet of the fish. The students will need to look at their data for that species and determine if the fish eats: zooplanton, snails, or both. They should think about what evidence they are using to make that decision.
5. After the students have completed the task, ask the students to report out to the class what fish species they looked at, what it was eating, and what trophic level it occupies. Make sure to have the students support their statements of the description by stating what evidence they are using.
6. After all of the groups have shared their results, show the students the graph of all of the fish data. Ask the students to make an assessment of the food web in the lake.

Q. Are most of the fish zooplanktivores? Are most benthivores? Are most omnivores?

Q. Are the fish across many trophic levels or are they in the same trophic level?

Q. What does that tell us about the lake ecosystem?

7. After the class discussion have the students write down an answer to the top question on page 2 of their handouts.

8. After a few minutes, ask the students if they think the diet of a fish changes with age. Remind them to think of other examples where the diet of an organism changes with age (humans).
9. Ask the students how they could go about testing to determine if the diet of a fish changes as it gets older. Help the students realize that they can repeat the same stable isotope analyses on muscle tissue from different size fish within the same species to determine if there are changes as the fish grows.
10. Have the students look at the graphs on their data sheet and answer the question, making sure to provide evidence to support their reasoning.

Make Sense (10 minutes)

1. After a few minutes, ask the students what patterns they observed in the data. Do fish change their diet over time? (burbot and minnow increase their trophic level, but the other four do not) Be accepting of all answers, this is meant to encourage students to use evidence in front of them to make conclusions.
2. After you have talked about the trophic levels vs. length graphs, again ask the students What does all of this diet information that tell us about the lake ecosystem. How would they describe the ecosystem and the fish living in it? Remind the students there are no right or wrong answers, but rather they are practicing using all of their information to make ideas.
3. Once the discussion slows down, point to the motivating question and ask:
   Q. How do scientists determine the diet of a fish and whether the diet changes over time?
   Ask students to share their ideas about the question with a partner. After a minute, ask volunteers to share the ideas they discussed with the entire class. Be accepting of all responses from the students. This is your opportunity to make sure the students understand the "take home message" that you identified.
4. Ask if the students have any final questions about the activity.

** Data and consultation for this lesson plan were provided by:
Talia Young and Dr. Olaf Jensen of Rutgers University. **

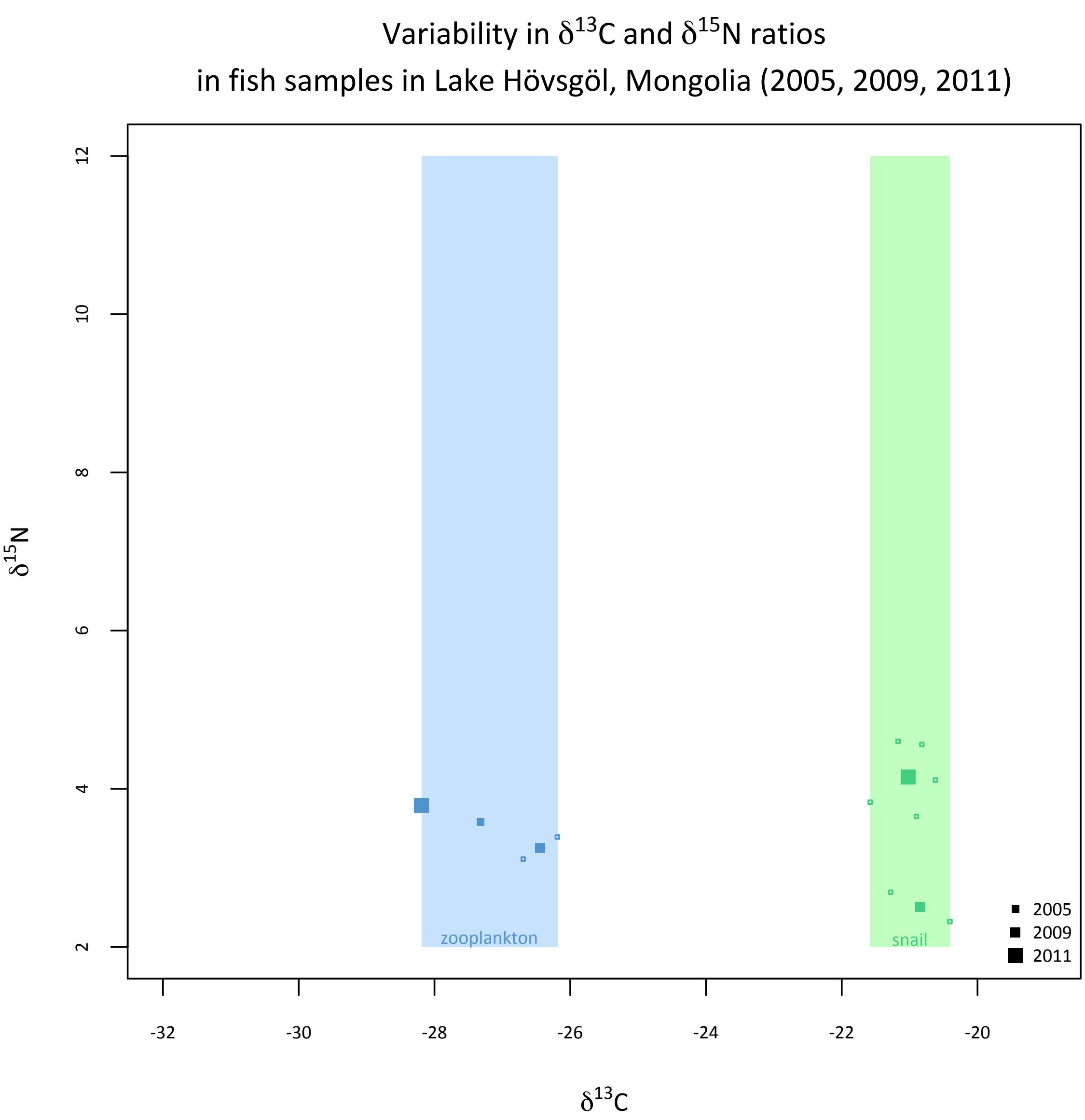
What Have You Been Eating? Worksheet

Name: ______________________________

Date: ______________________________

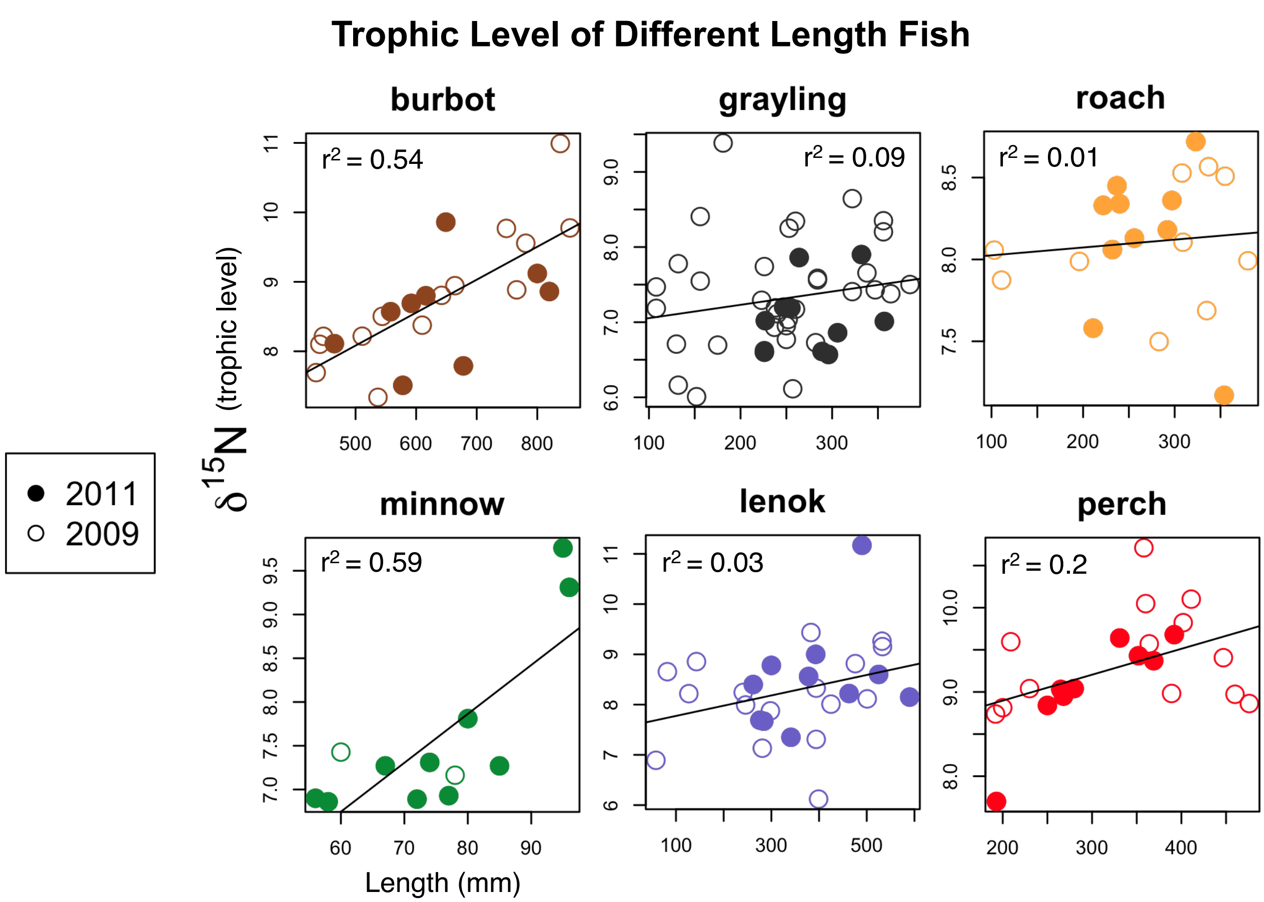
Can we tell what a fish eats from looking at its muscle tissue?

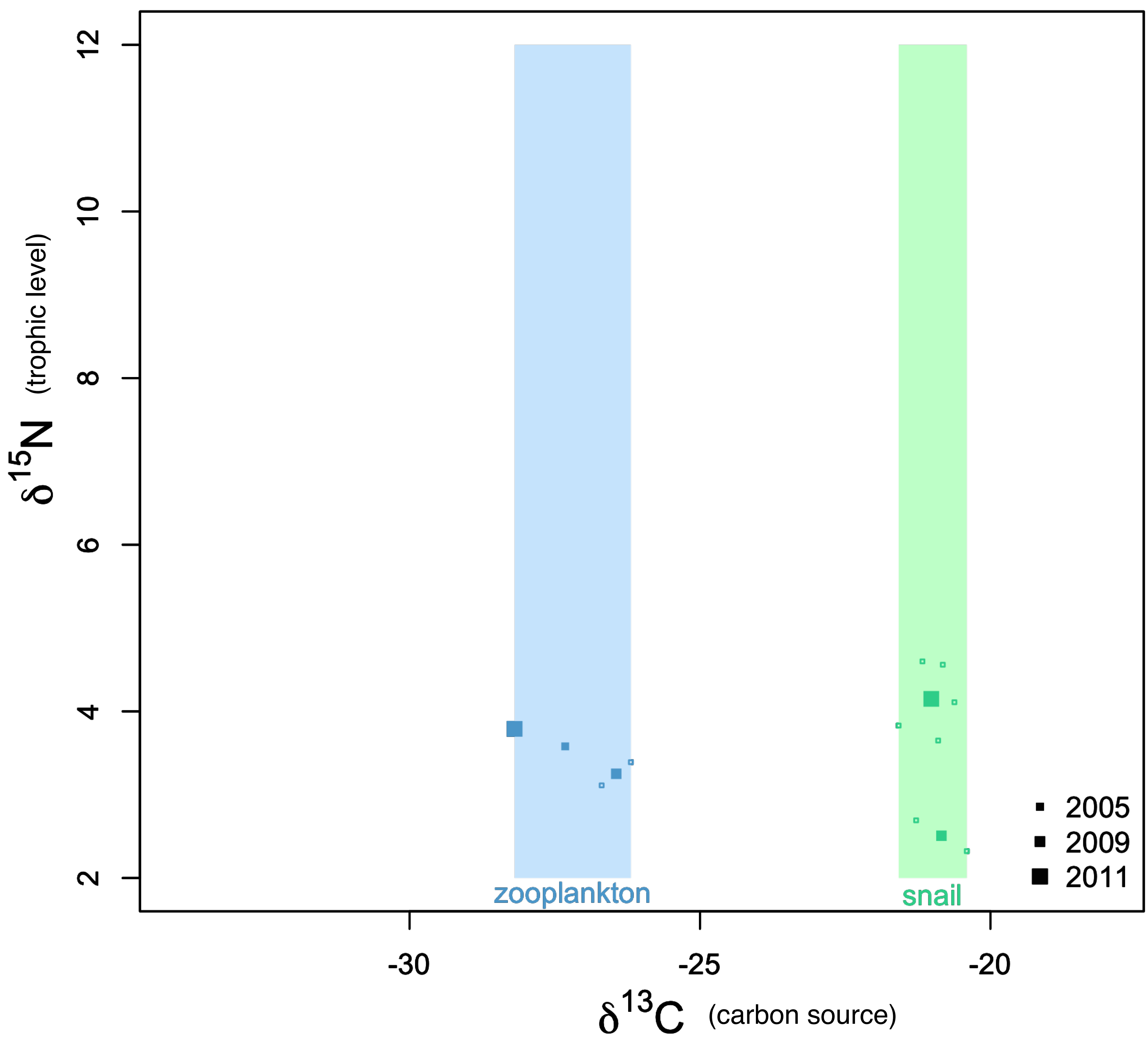
Fish Name: _____________________ Add the data for your fish species onto the graph. What does your fish eat? What evidence are you using to make that statement?



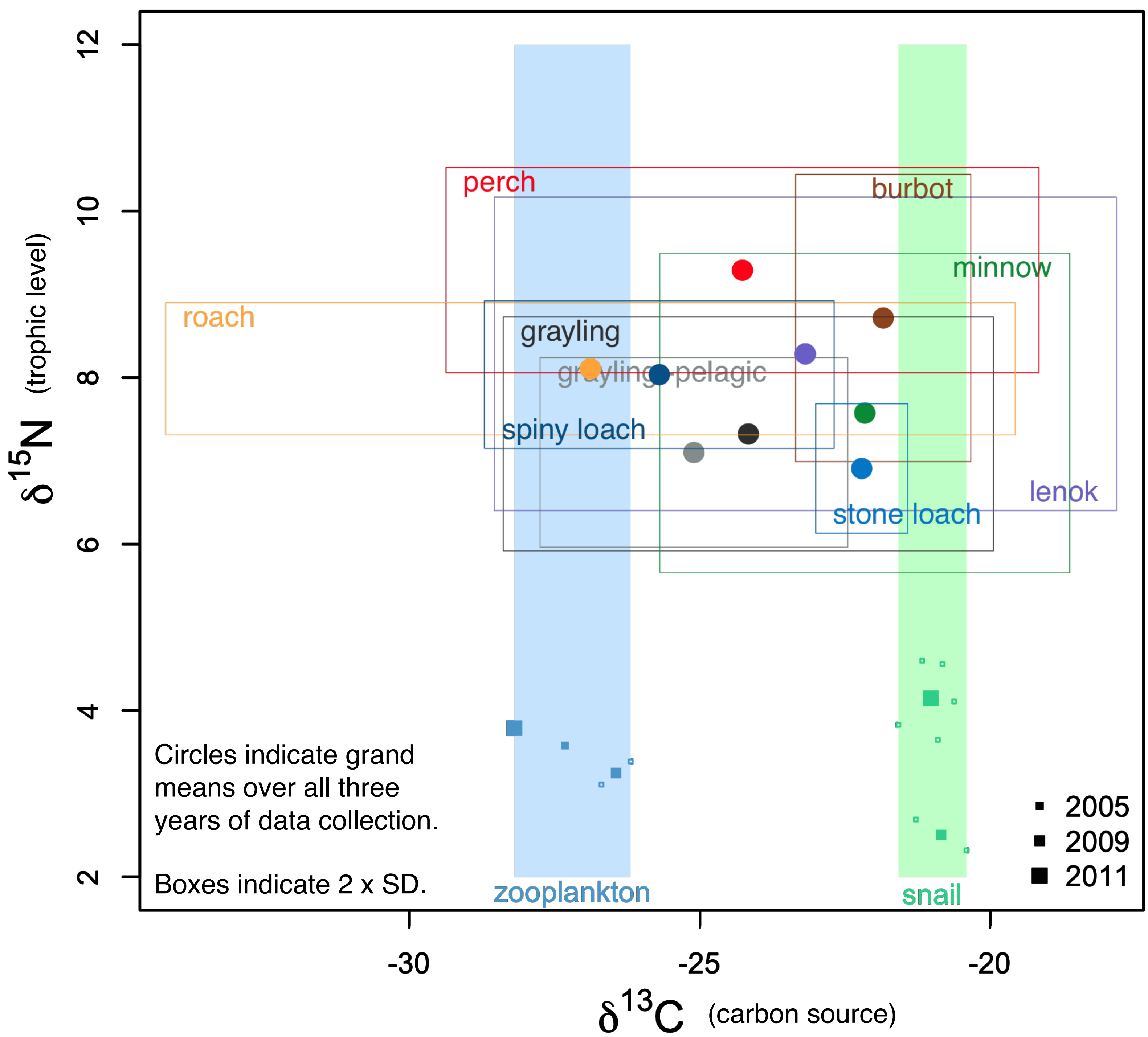
What can we learn about the lake ecosystem when looking at all of the data together?

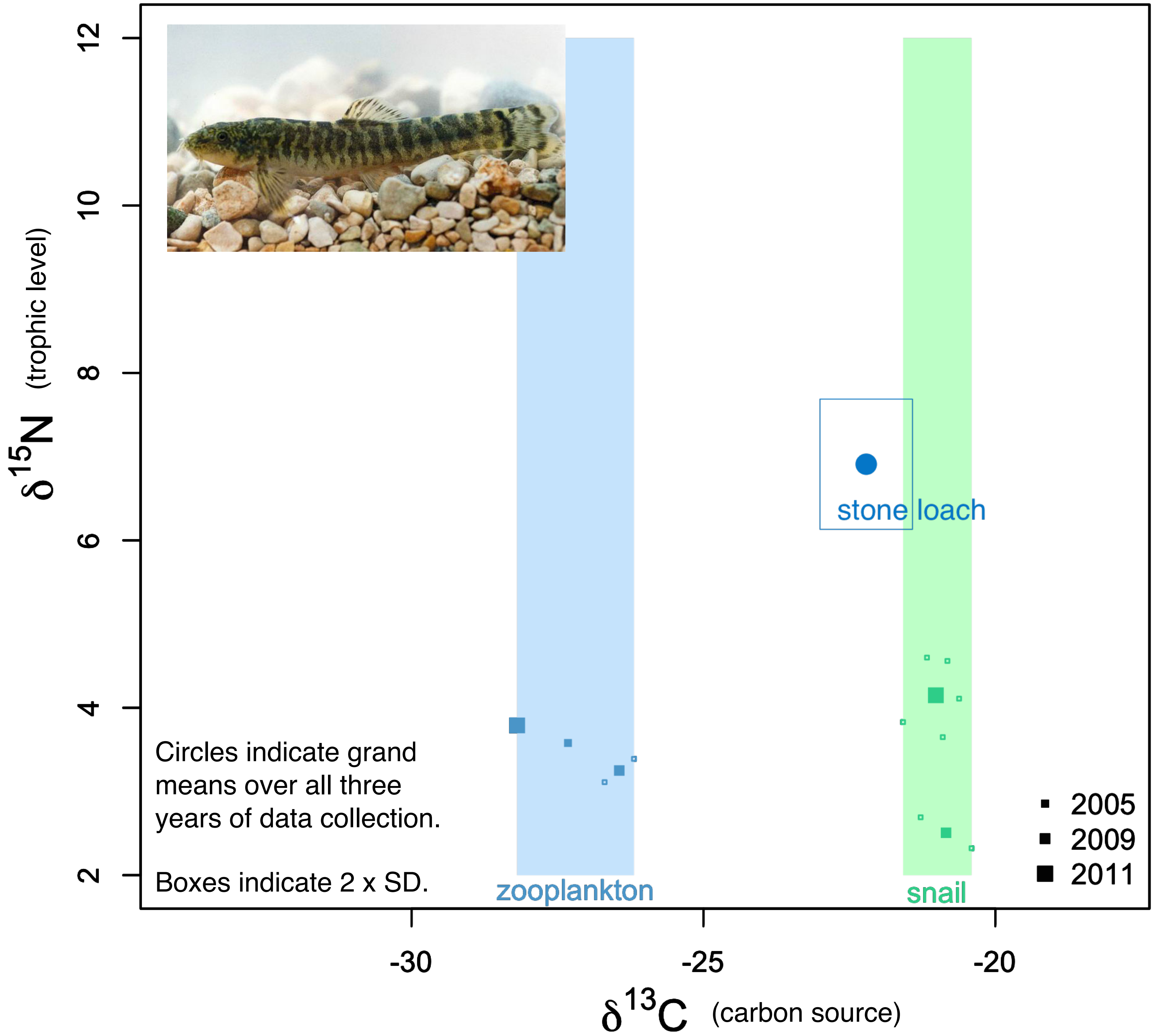
Do fish move up the food chain as they grow older? If so, which ones, what evidence are you using, and why do you think that is? If not, which ones and why do you think that is?



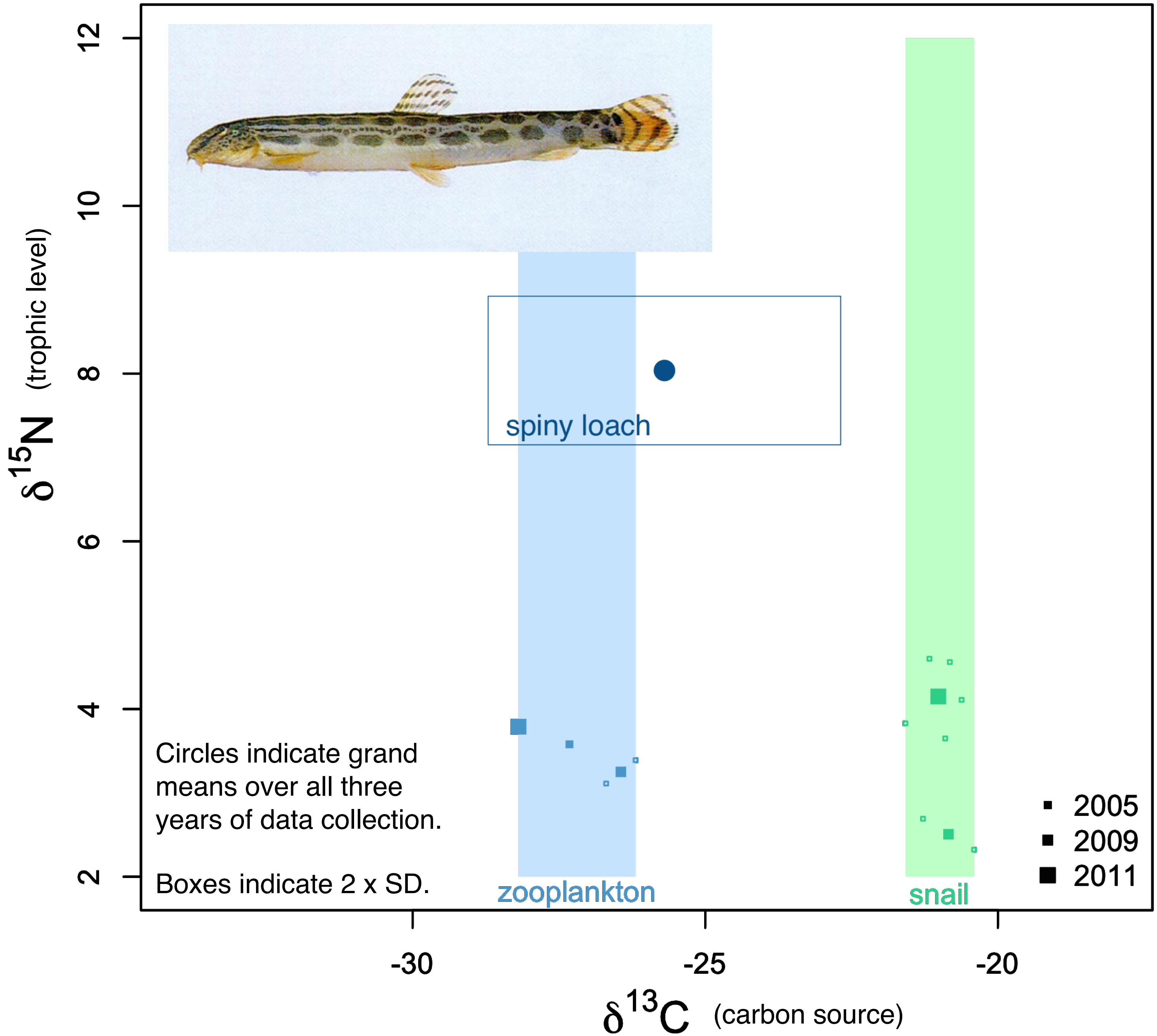


12
10
8
6
4
2
δ15N (trophic level)
-30
-25
-20
δ13C (carbon source)
zooplankton
snail
2005
2009
2011

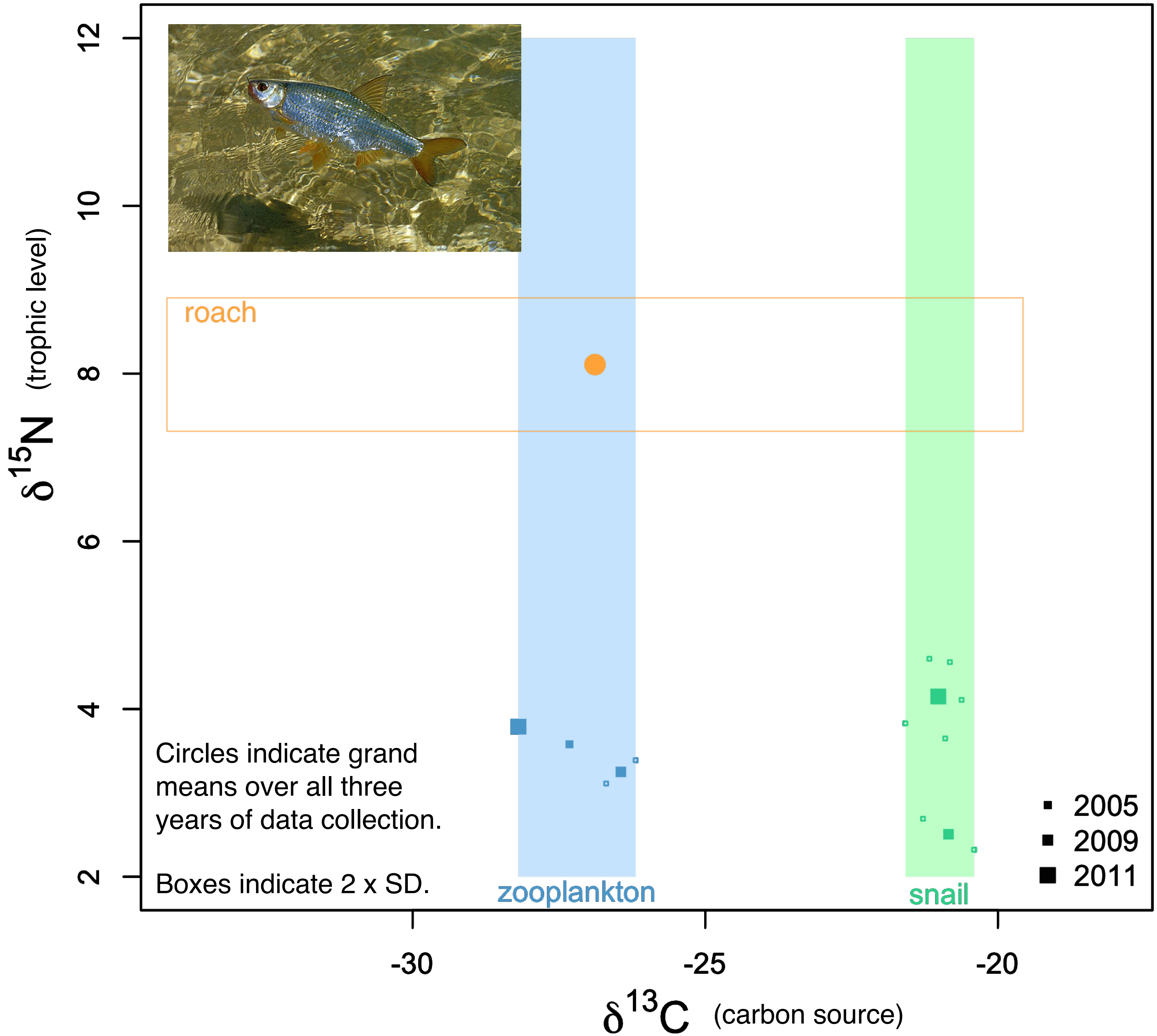

perch
burbot
minnow
roach
grayling
grayling pelagic
spiny loach
lenok
stone loach
zooplankton
snail
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011
12
10
8
6
4
2
-30
-25
-20
$\delta^{15}N$ (trophic level)
$\delta^{13}C$ (carbon source)



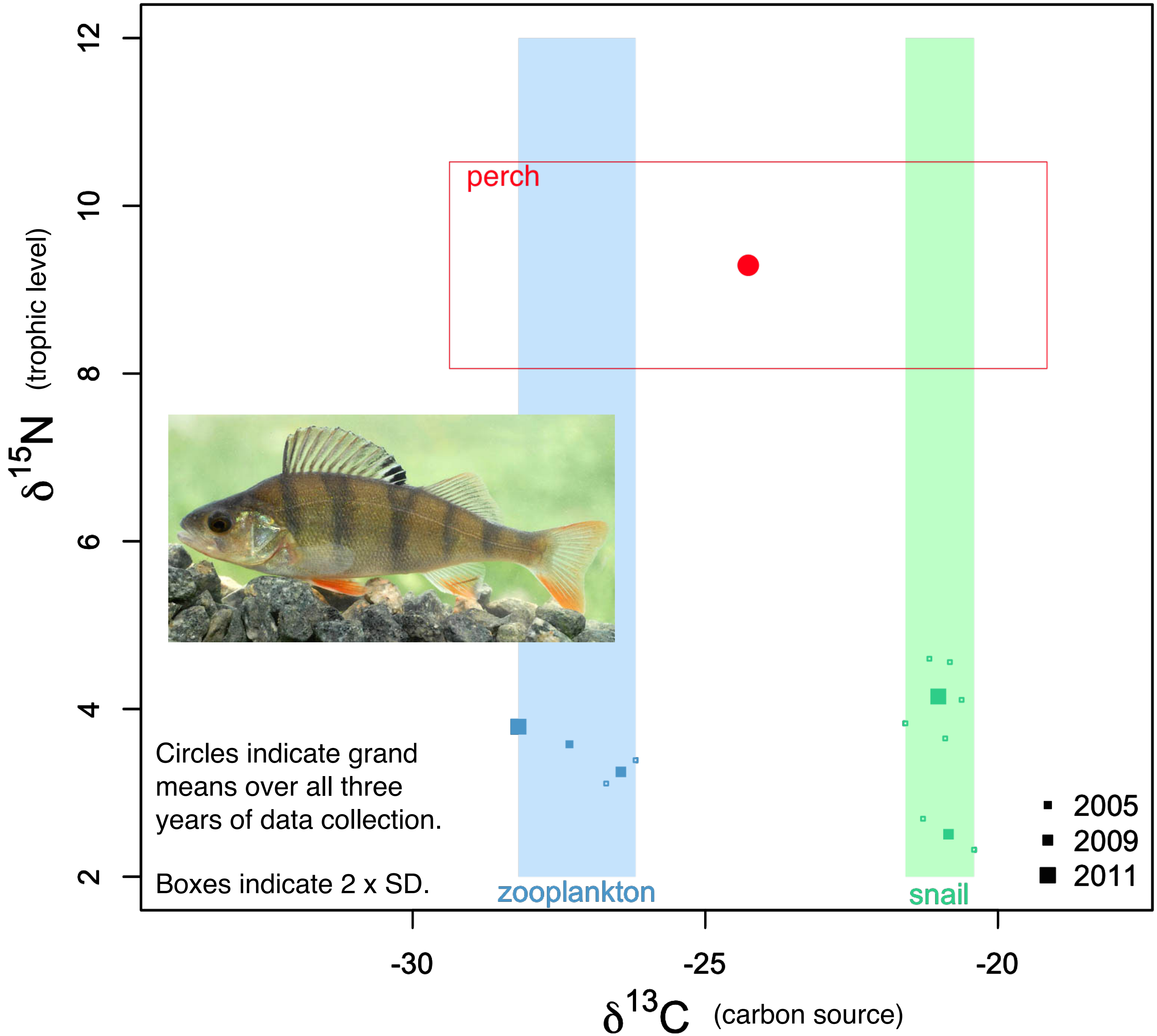
12
10
8
6
4
2
$\delta^{15}N$ (trophic level)
-30
-25
-20
$\delta^{13}C$ (carbon source)
stone loach
zooplankton
snail
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011

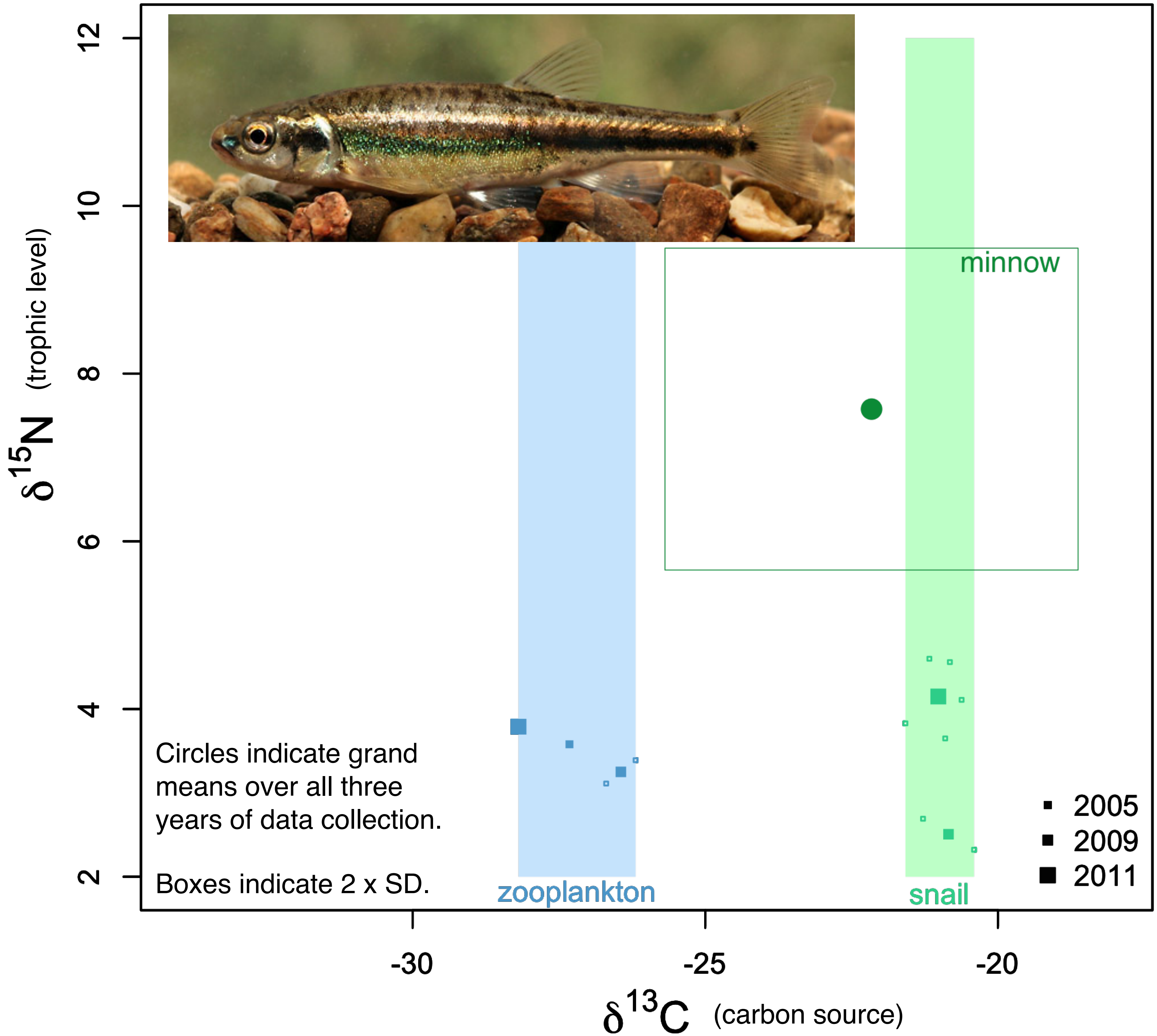


spiny loach
zooplankton
snail
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011
-30
-25
-20
2
4
6
8
10
12
δ13C (carbon source)
δ15N (trophic level)

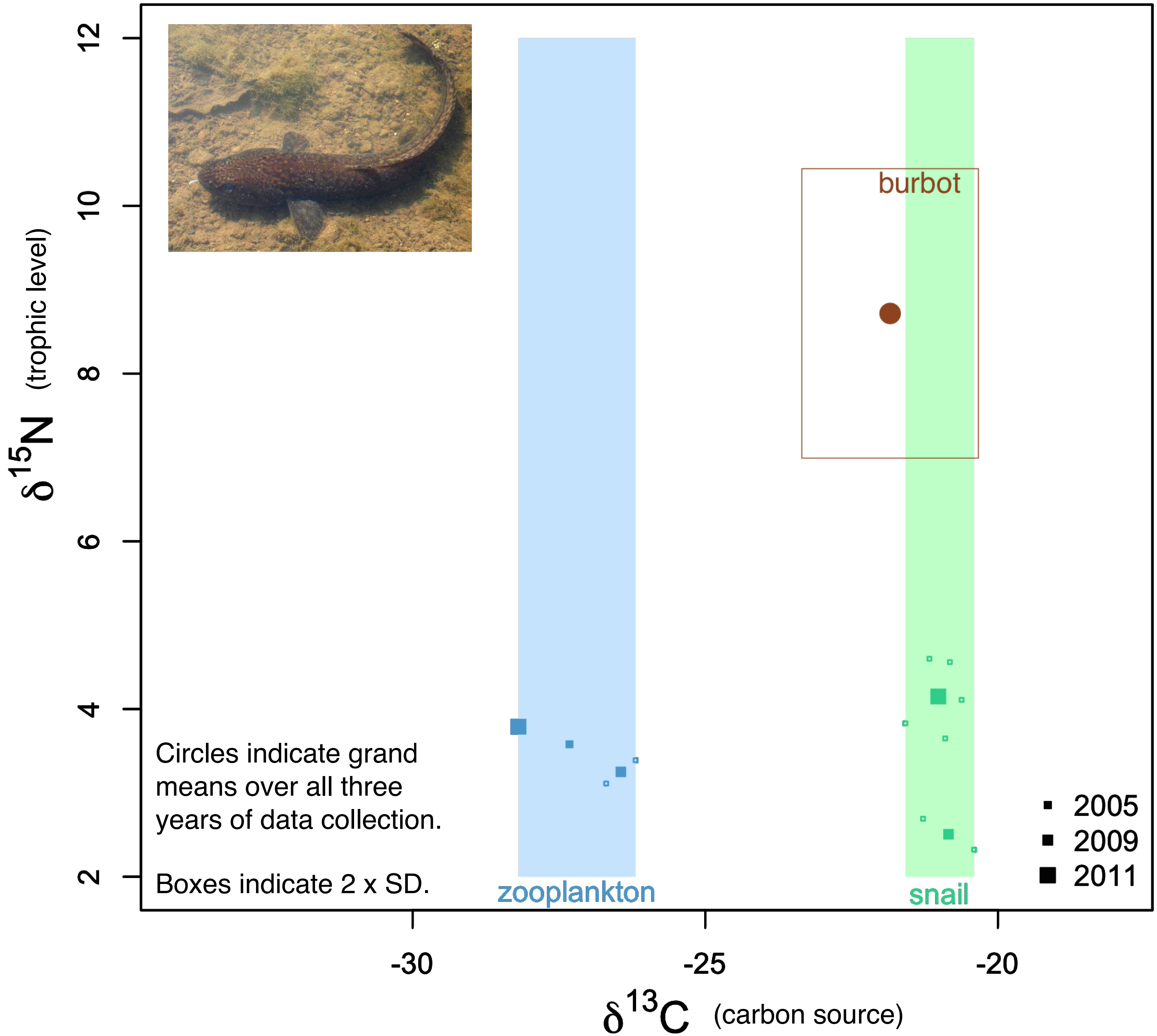


roach
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
zooplankton
snail
2005
2009
2011
δ15N (trophic level)
δ13C (carbon source)
12
10
8
6
4
2
-30
-25
-20

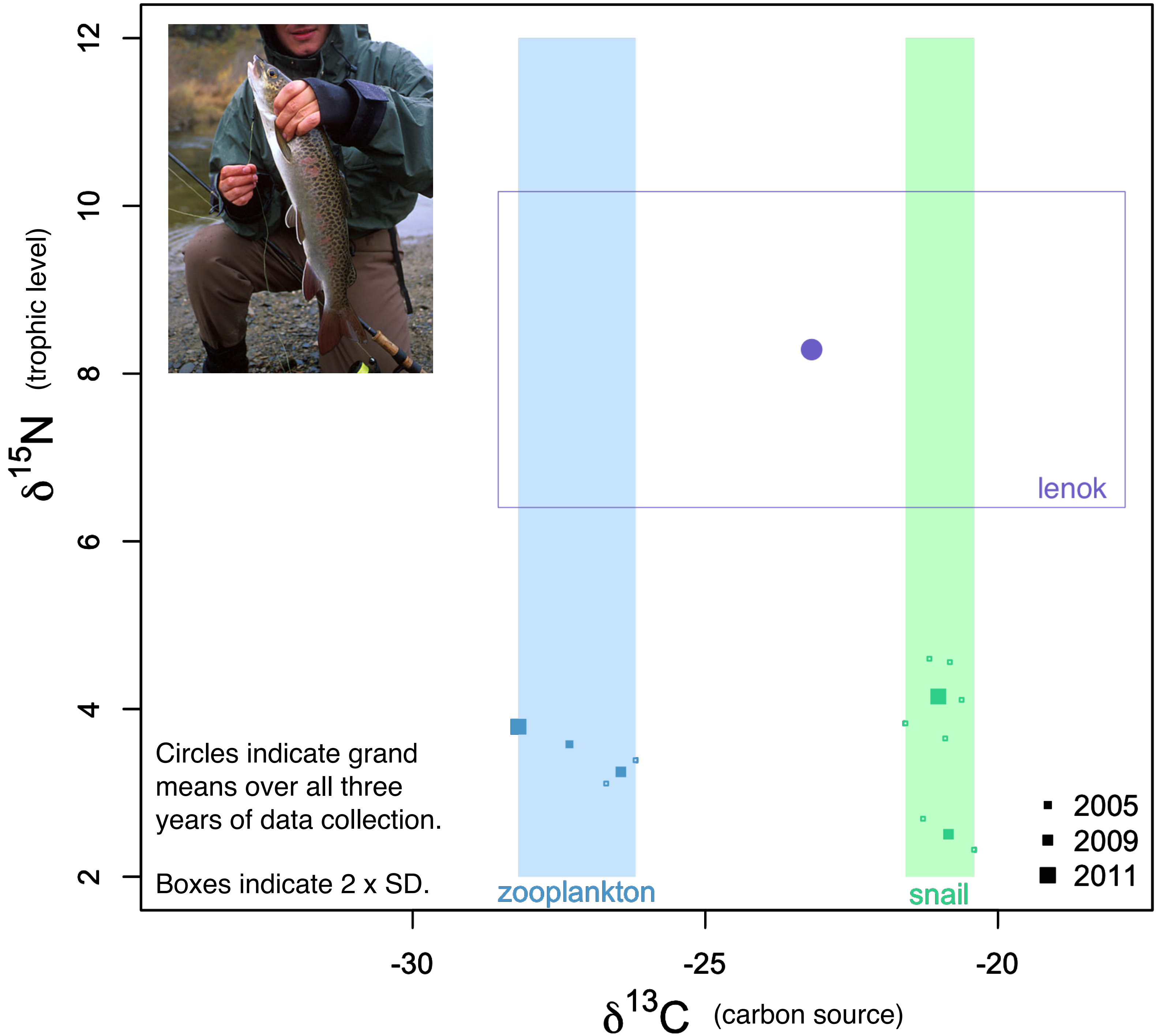

perch
zooplankton
snail
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011
δ15N (trophic level)
δ13C (carbon source)
2
4
6
8
10
12
-30
-25
-20

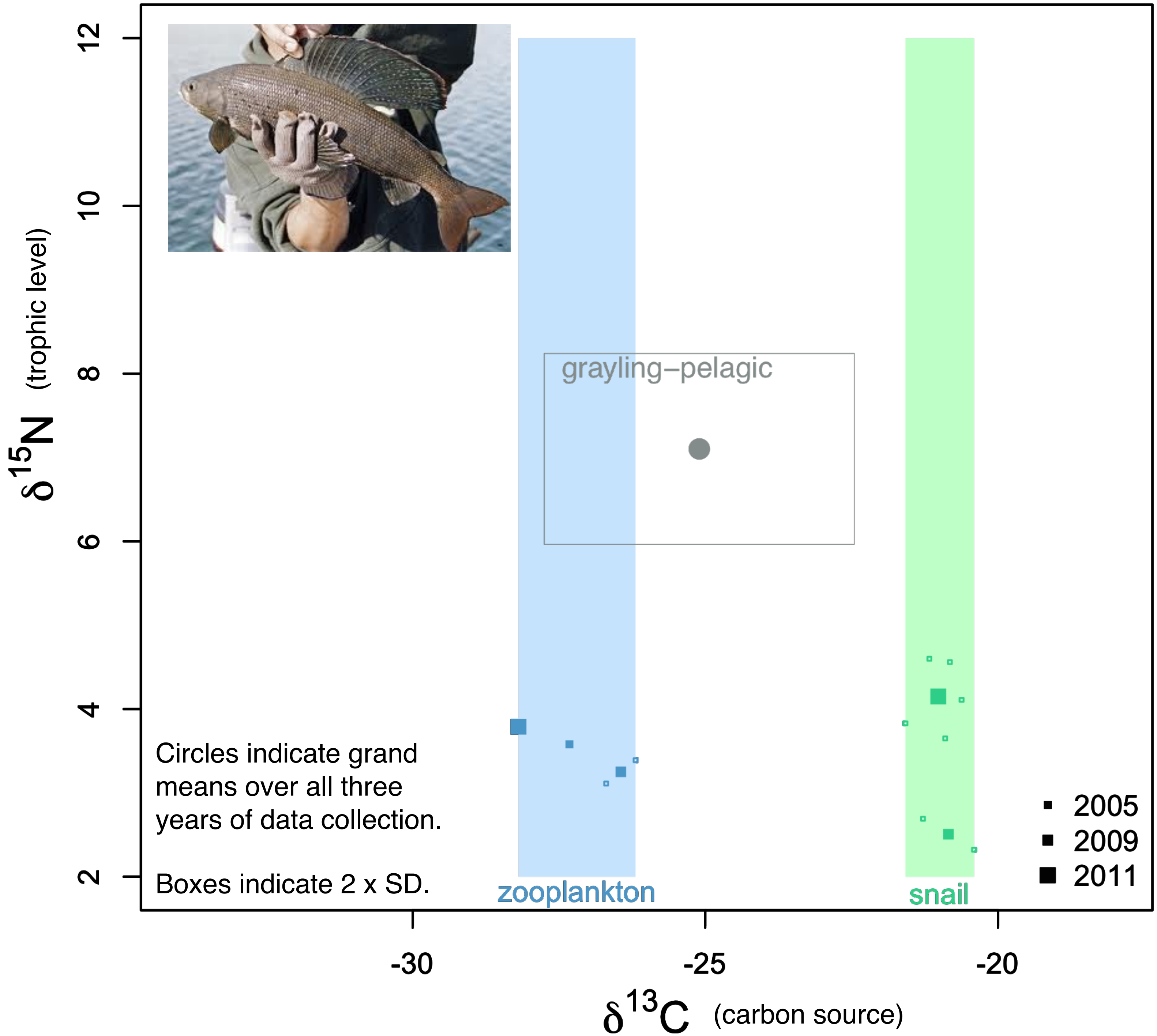


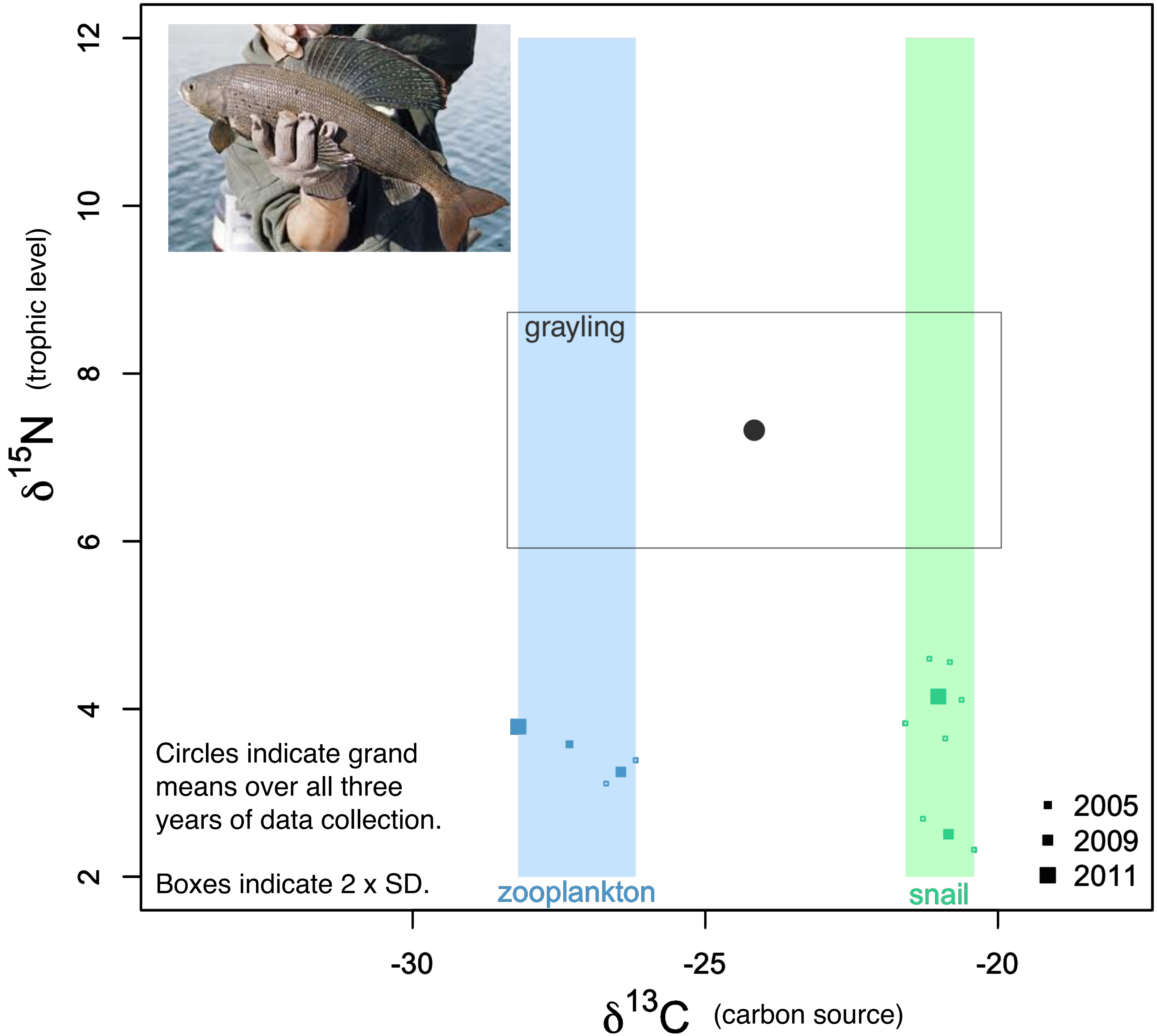
minnow
zooplankton
snail
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011
12
10
8
6
4
2
-30
-25
-20
δ15N (trophic level)
δ13C (carbon source)



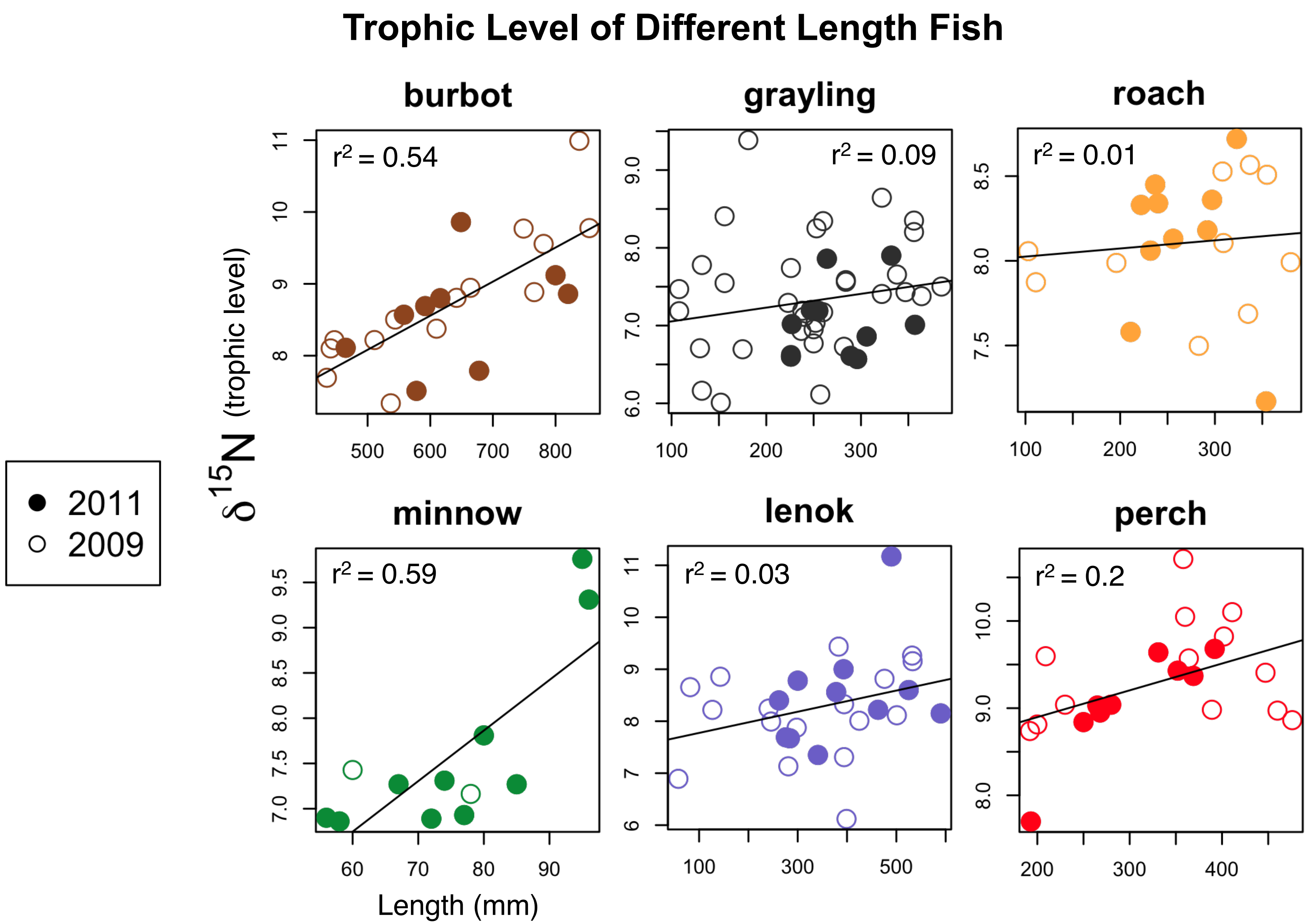
12
10
8
6
4
2
δ15N (trophic level)
-30
-25
-20
δ13C (carbon source)
zooplankton
snail
burbot
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011


δ15N (trophic level)
δ13C (carbon source)
12
10
8
6
4
2
-30
-25
-20
zooplankton
snail
lenok
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011


12
10
8
6
4
2
δ15N (trophic level)
grayling–pelagic
zooplankton
snail
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011
-30
-25
-20
δ13C (carbon source)



grayling
zooplankton
snail
Circles indicate grand means over all three years of data collection.
Boxes indicate 2 x SD.
2005
2009
2011
δ15N (trophic level)
δ13C (carbon source)
-30
-25
-20
2
4
6
8
10
12


Trophic Level of Different Length Fish
burbot
grayling
roach
minnow
lenok
perch
r2 = 0.54
r2 = 0.09
r2 = 0.01
r2 = 0.59
r2 = 0.03
r2 = 0.2
δ15N (trophic level)
Length (mm)
2011
2009