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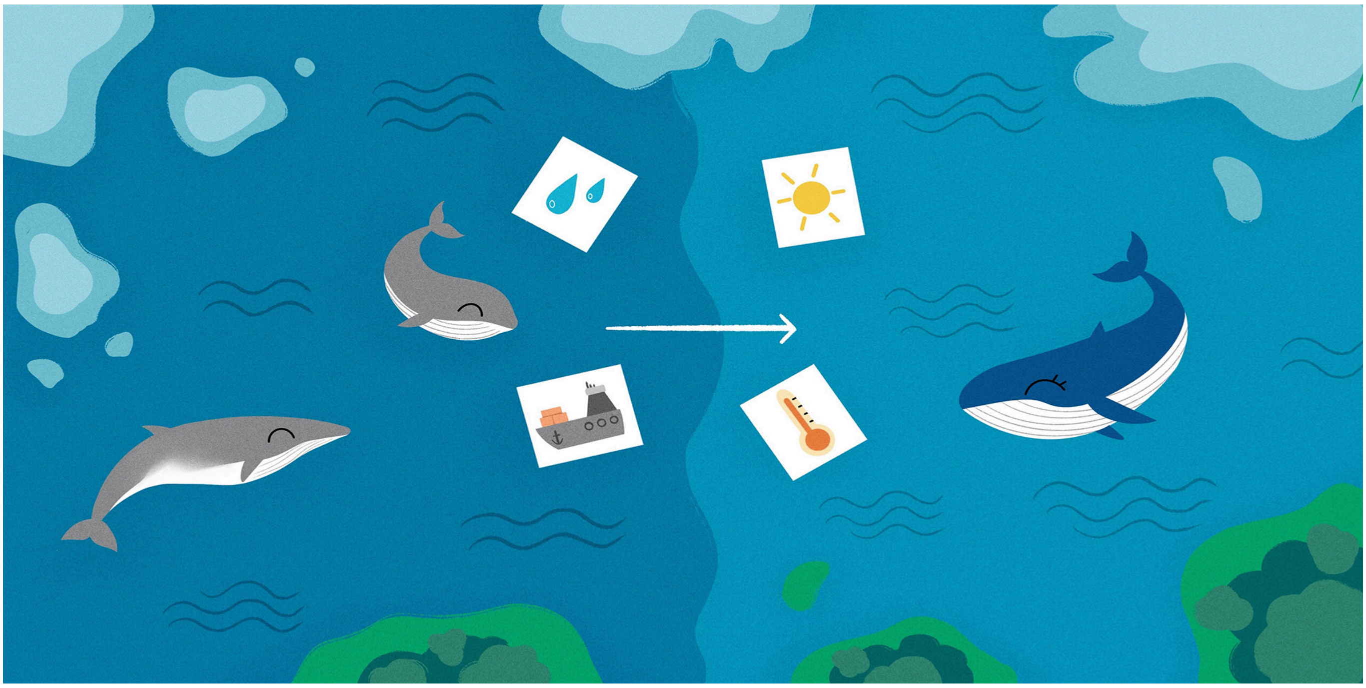

MOVING HYBRID ZONES; WHEN TWO SPECIES MEET, MATE, AND COMPETE

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YOUNG REVIEWERS:

ANVITHA
AGE: 11

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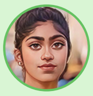

SRINIKA
AGE: 11

When parents of two different species have babies together, those babies are called hybrids. In nature, hybrids are often born in the region where the ranges of their parent species meet. This region is called a hybrid zone. We know that species change their ranges all the time, and we also know that some species compete with each other for food or living space. This means that, if one of the two parent species manages to expand its range, the other species may be forced to retreat. If that were to happen, the hybrid zone between the two species' ranges should move, right? Even though researchers used to think that hybrid zone movement was rare, recent studies suggest otherwise. In this article, we will tell you what hybrid zones are, how they form, why their position may shift over time, and what we can learn from this movement.

WHAT IS A HYBRID ZONE?

When two closely related animal or plant species breed together, the resulting offspring are called hybrids. You may have heard of a hybrid called a liger, a cross between a lion and a tiger. However, ligers do not occur in the wild—they have only been bred with human help in zoos. Hybridization can also occur in nature. For instance, the two largest animals on Earth, the blue whale and the fin whale, occasionally produce hybrids [1]. But how come the species that hybridize do not blend into a single species?

Hybrids typically have lower **fitness** than their parents—they are less healthy and produce fewer babies. That is because the **genes** of the two species that produced them have trouble working together. For example, hybrids between horses and donkeys cannot have babies themselves. As a consequence, the two parent species do not merge into a new species, instead they remain distinct. Still, if these species continue to mix, a narrow band will remain in between their **distribution ranges**, where hybrids keep being produced (Figure 1A). This region is called a **hybrid zone** [2].

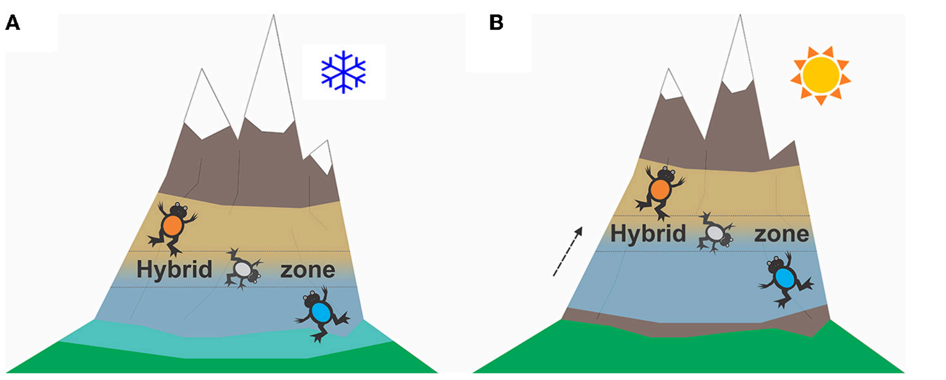

Figure 1

CAN HYBRID ZONES MOVE?

Traditionally, researchers thought hybrid zones should pretty much stay in the region where the parent species first met and started hybridizing. But what if one of the two parent species is better **adapted** to the local environment than the other, at the location where they first meet? Or what if the environment changes in favor of one of the parent species, because the environment gets warmer or wetter, for example? Under such circumstances, you would expect one of the two parent species to **outcompete** the other one. The better-adapted species expands its range at the expense of the less-adapted one, which in turn is forced to surrender part of its range (Figure 1B).

As a result, the hybrid zone in between the ranges of the two species moves [3]. This movement continues until the hybrid zone reaches a

FITNESS

How successful an individual is in producing offspring compared to other members of its species.

GENE

Segments of DNA that contain information about traits, like eye color, that can be passed on from parents to their offspring.

DISTRIBUTION RANGE

The geographical area where a species can be found.

HYBRID ZONE

The area where two species meet, mate, and produce offspring.

Figure 1

Hybrid zones can shift over time. **(A)** The blue toad is found at low elevation and the orange toad at high elevation. They meet in a narrow band in between, where they produce hybrids: a hybrid zone. **(B)** Due to increasing temperatures, both species move further up the mountain. Their hybrid zone shifts upwards as well.

ADAPTATION

A trait that makes an individual better suited to deal with a particular environment and that can be inherited by that individual's offspring.

OUTCOMPETE

To be more successful than another species in obtaining resources (such as food or living space), so that the more successful species replaces the less successful one.

point where both species are equally well-adapted to the environment, or until one species has completely replaced the other. This all seems to make sense, but is there any evidence for such hybrid zone movement? Recent studies say yes!

DIRECT OBSERVATIONS OF HYBRID ZONE MOVEMENT

Researchers have been studying certain hybrid zones for decades now. And for some of these hybrid zones, they have observed movement "live". A particularly well-studied case is that of chickadees, small birds that occur in North America. Warming temperatures have caused the hybrid zone between black-capped chickadees and Carolina chickadees to shift northward by over 10 km in a decade [4].

Researchers mapped the distribution of the two chickadee species each year, based on sightings of birdwatchers reported in the **citizen science** database eBird. By comparing the distribution over the years, the researchers revealed the gradual movement of the chickadee hybrid zone, with the Carolina chickadee pushing out the black-capped chickadee (Figure 2). Examples such as this provide undeniable evidence that hybrid zones can and do move, at least over relatively short periods.

CITIZEN SCIENCE

A practice in which regular citizens participate in and help with scientific research by, for example, monitoring birds or other animals.

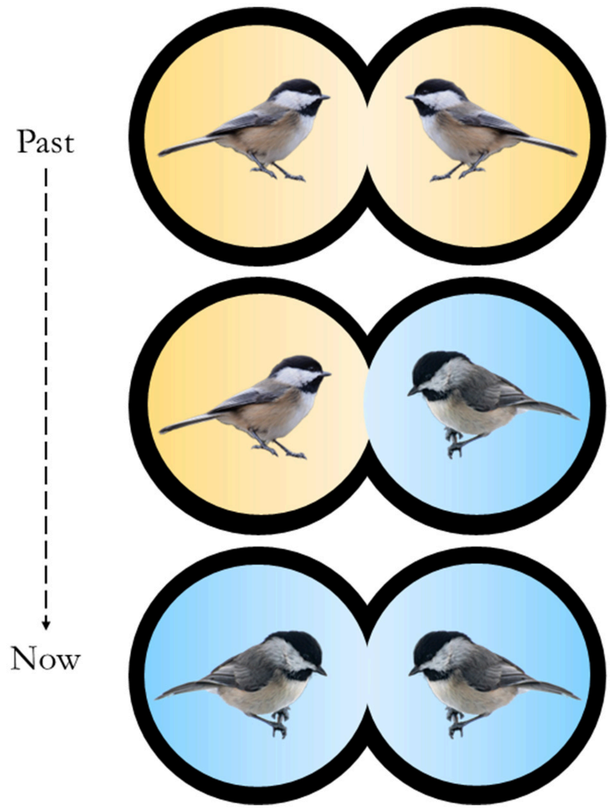

Figure 2

Figure 2

As the Carolina chickadee (blue) expanded its range northward, it forced the black-capped chickadee (orange) to retreat. In places just north of the former location of the hybrid zone, only black-capped chickadees used to be seen by birdwatchers. Gradually, more and more Carolina chickadees were spotted, until eventually *only* Carolina chickadees were reported. This tells us that, in some cases, we can see hybrid zones moving in "real time".

LONG-TERM HYBRID ZONE MOVEMENT

Many hybrid zones are already thousands of years old. This means that they may have moved over huge distances (many hundreds of kilometers). However, nobody was around to see it. Still, we can figure out if these hybrid zones have moved by studying the genes of the hybridizing species. Some genes of the species whose range was pushed back are expected to be left behind in the species that is expanding its range. This tell-tale pattern of left-behind genes has been called a genomic footprint of hybrid zone movement [5]. A good example is provided by crested newts in Turkey (Figure 3). Here, genes of the retreating Balkan crested newt can be found in the advancing Anatolian crested newt. Such a genomic footprint allows us to determine that a hybrid zone has moved, even many centuries after it happened. This exchange of genes between species that allows us to see the genomic footprint is called **introgression**. Introgression also applies to humans, as many of us possess a bit of Neanderthal DNA resulting from past hybridization between Neanderthals and early modern humans. The direction of introgression can reveal past hybrid zone movement.

INTROGRESSION

The exchange of genes between two species following hybridization.

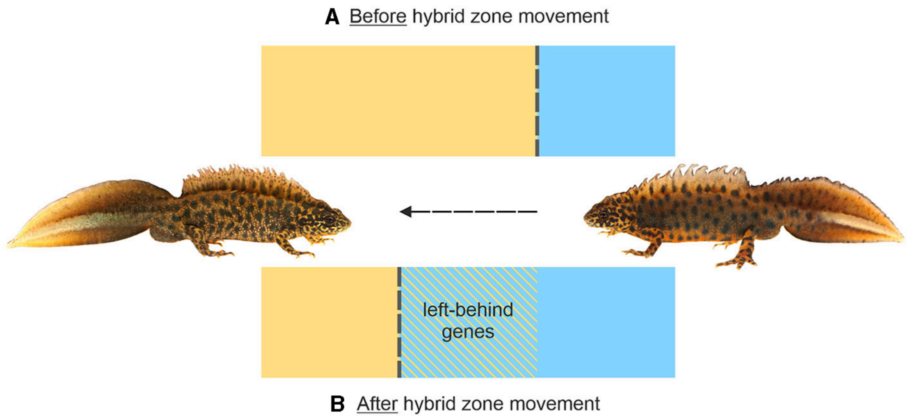

Figure 3

Studying a species' genes can tell us about the long-term movement of hybrid zones. **(A)** In the past, the Balkan crested newt (orange) and the Anatolian crested newt (blue) met at a hybrid zone. **(B)** Later, the Anatolian crested newt expanded its range and pushed out the Balkan crested newt, causing the hybrid zone to shift as well. Genes of the Balkan crested newt could be found in Anatolian crested newts in the newly acquired part of their range.

WHY IS HYBRID ZONE MOVEMENT INTERESTING?

That species regularly need to change their ranges in response to one another is an important realization in biogeography (the study of life's distribution across the Earth). Nowadays, humans are causing hybrid zone movement. By transporting species all over the world, we bring species together that did not previously meet in nature, and potentially create new hybrid zones. When the newly introduced species subsequently outcompetes the native one, the hybrid zone moves. This is again illustrated by crested newts: in western Europe the Italian crested newt has been regularly introduced inside the range of the northern crested newt—a species of conservation concern. Because the two crested newt species can hybridize, we now observe hybrid zones that are expanding outwards from the original introduction sites.

Furthermore, by modifying species' habitats and contributing to climate change, we are shifting the balance of which member of a hybridizing species pair is most successful [6]. While these man-made changes happened only recently compared to the natural processes that shape hybrid zones, we can expect hybrid zones to form—and move—in response. You could even consider hybrid zones as an indicator of global change [7].

CONCLUSION

Hybrid zone movement seems to be much more common than previously assumed. Perhaps it should even be considered the rule rather than the exception? Hybrid zones have been moving in response to past global changes and therefore can be expected to move in response to future global changes—including those caused by us. In fact, studying hybrid zone movement helps us to anticipate how species might respond to ways that humans are changing the planet.

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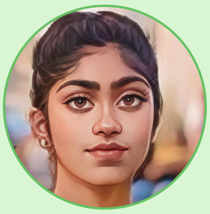
CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ANVITHA, AGE: 11
My name is Anvitha and I think polar bears are awesome! I also love music; dancing to it, making it or just listening to it. I enjoy learning about what is going on in the world, so I am really happy to be a young reviewer for the journal Frontiers in Young Minds.

KABIR, AGE: 9
My name is Kabir! I am a rising 4th grader. I like to do math, art, and be creative. I enjoy creating things out of cardboard with my dad. At home, the friends I play with are my stuffed dogs. I imagine that they talk, move, and even have special superpowers! I also like to play board games, and bike with my parents. When my dad is home, we play piano, and we all have fun talking while eating dinner!

KAUSHIK, AGE: 8
I like drawing and painting very much. I gift my paintings to my friends. I like to play with my friends. I am also interested in athletics. I also enjoy traveling to wildlife parks and jungle safari.



SRINIKA, AGE: 11

My name is Srinika, and I love trying new things. I love playing chess, drawing, and biking. I also love the outdoors. My favorite subjects are math and science. I hope, that someday in the future, I become a doctor.

AUTHORS

NIENKE PRINS

Nienke is a biology student at the University of Leiden, in the Netherlands. Amphibians are her favorite group of animals. For her bachelor's degree, she used genomic tools to determine the origin of introduced spadefoot toads, and for her master's degree, she studied the dynamic history of a hybrid zone between two species of crested newt. Aside from doing research, she also engages in science communication. In her free time, Nienke reads tons of books about all kinds of interesting stuff. She enjoys hiking, gaming, and writing as well. *prinsnienke867@gmail.com

BEN WIELSTRA

Ben loves animals and one of his earliest childhood memories is catching a male smooth newt with a dip net. During his biology studies, Ben rekindled his love for newts—he has been studying them ever since. After his Ph.D. studying newt biogeography, Ben left the Netherlands for two postdoctoral fellowships on newt hybrid zones, at the University of Sheffield (UK) and the University of California, Los Angeles (USA). Now Ben is back home in Leiden as an assistant professor, studying many aspects of newt evolution. Ben's passion outside of work is birdwatching.