Dive to Survive

LEARNING OUTCOMES

- Describe and explain the diving ecology of an arctic marine animal.

- Explain how tidal currents affect sea ice habitats and influence the animals that live there.

- Use the concepts of trigonometry to solve applied problems.

OVERVIEW

Eider ducks dive under the sea ice to eat mussels and urchins. The time it takes to get to the bottom depends on the water depth and the speed of ocean currents. In this exercise students will use basic geometry to evaluate the relationships between depth, swim speed, and travel time, and discuss the usefulness of scientific investigations of this kind.

FLOW

1. Pre-discussion questions
2. Watch Eider Duck Dive video
3. Teacher directed pre-discussion
4. Students complete worksheet
5. Teacher reviews worksheet
6. Post-discussion questions

CONTENTS

STUDENT OVERVIEW

WHY?

To understand the factors involved in eider duck feeding, from dive angle to differing ocean currents.

WHAT?

- How eider ducks dive to the seafloor to find food
- How ocean currents affect arctic animals like eider ducks
- How to use the Pythagorean theorem and law of cosines

HOW?

(?) Pre-discussion questions

(▷) Watch a video about eider ducks

(💬) Talk about what you already know about eider ducks, ocean currents and how to solve triangles

(▷) Watch video footage of eiders diving

(✏) Complete worksheet

(?) Post-discussion questions

IMAGE 1 Common Eider, Mitiq ᒥᑎᖅ ᐊᓗᐃᑦᔭᐊᖅ, Somateria mollissima (S. DesRoches)

BACKGROUND

Some populations of the Common Eider duck live in the Arctic through the winter. These eider ducks depend on areas of open water in the sea ice where they can dive down and feed on seafloor invertebrates such as mussels and urchins. Despite the freezing winter temperatures, some areas in Hudson Bay remain ice free during the Arctic winter. Sections of open water in an ocean of ice are called **polynyas**, while long cracks in the sea ice are called **flaw leads**. These are truly the oases of the Arctic as they allow a number of animals to access food as well as marine mammals to access breathing air.

Part of the complex Arctic food web, eider ducks are an important resource for Arctic foxes and snowy owls. They are also harvested by Inuit on the Belcher Islands for both food and clothing. See the Resources section for a video showing how eider parkas are made.

IMAGE 2 It takes between 20 and 30 eider skins to make a traditional eider parka. (J.Heath)

Diving beneath the waves may come naturally to a duck, but factors such as strong ocean currents and water depth mean an eider rarely executes a perfect straight-down dive. By adopting a certain **dive angle**, a duck can compensate for the water conditions to successfully reach its prey. Strong currents keep the water from freezing, but also increase the difficulty of diving as the ducks have to swim into the current to reach the food on the bottom. Using underwater video, researchers can determine how long it takes the ducks to get to the bottom in different currents, estimate their dive angle and follow individuals hunting for mussels and sea urchins on the seafloor.

VOCABULARY

Abiotic: Non-living elements of the environment (antonym of biotic).

Flaw lead: Cracks in sea ice sheets that open up due to wind and often freeze over again.

Oasis: (oases pl.) Provides habitat for animals; contains an isolated feeding ground and/or shelter.

Polynya: An area of open water surrounded by sea ice; often remains open throughout the winter.

Dive Angle: The angle at which an eider duck dives down to the bottom relative to the surface of the water.

Physiological: Relates to a living thing's health or normal functioning.

Ecological: Deals with the relationships between groups of living things and their environments.

Tidal Ebb: when the tide is going out.

Tidal Flood: when the tide is coming in.

PREPARATION

MATERIALS

- Calculator
- Protractor
- Stopwatch/timer

RESOURCES

▶ **Dive Video #1**
Video of eider duck diving for worksheet Part 1
https://arcticeider.com/links/dts8

▶ **Dive Video #2**
Video of eider duck diving for worksheet Part 2
https://arcticeider.com/links/dts9

▶ **Eider Studies Video**
A special feature from the film People of a Feather, which touches on how eiders survive in a harsh climate
https://arcticeider.com/links/dts1

IMAGE 3 The eider duck on the right is diving under the sea ice against the current. (J.Heath)

PROCEDURE

In this lesson, students will use diving videos and trigonometry to analyse the diving behaviour of eider ducks.

1. On the board write the following terms and brainstorm what students know about them.

    * Eider
    * Polynya
    * Currents

2. Share information about eider duck ecology from the background section and watch the Eider Studies Video (pg. 4). The key points to cover are:

    Strong tidal currents can keep polynyas and flaw leads open,

    Eider ducks feed at these openings in the sea ice and need to swim against the current so that they don't get swept under the ice,

    The angle at which eiders dive is influenced by the velocity of the current, which also influences the time it takes to get to the bottom to feed.

3. Put one of the Pre-discussion Questions (pg. 13) questions up on the board and brainstorm answers together as a class or divide the questions up between groups and do a jigsaw activity.

4. Tell students to put themselves in the shoes of researchers who want to know more about the challenges faced by diving eider ducks. Help students work through the accompanying Worksheet (pg. 6), and make sure there is a place for them to view the diving videos. There are two parts to the worksheet. Review worksheet answers as a class.

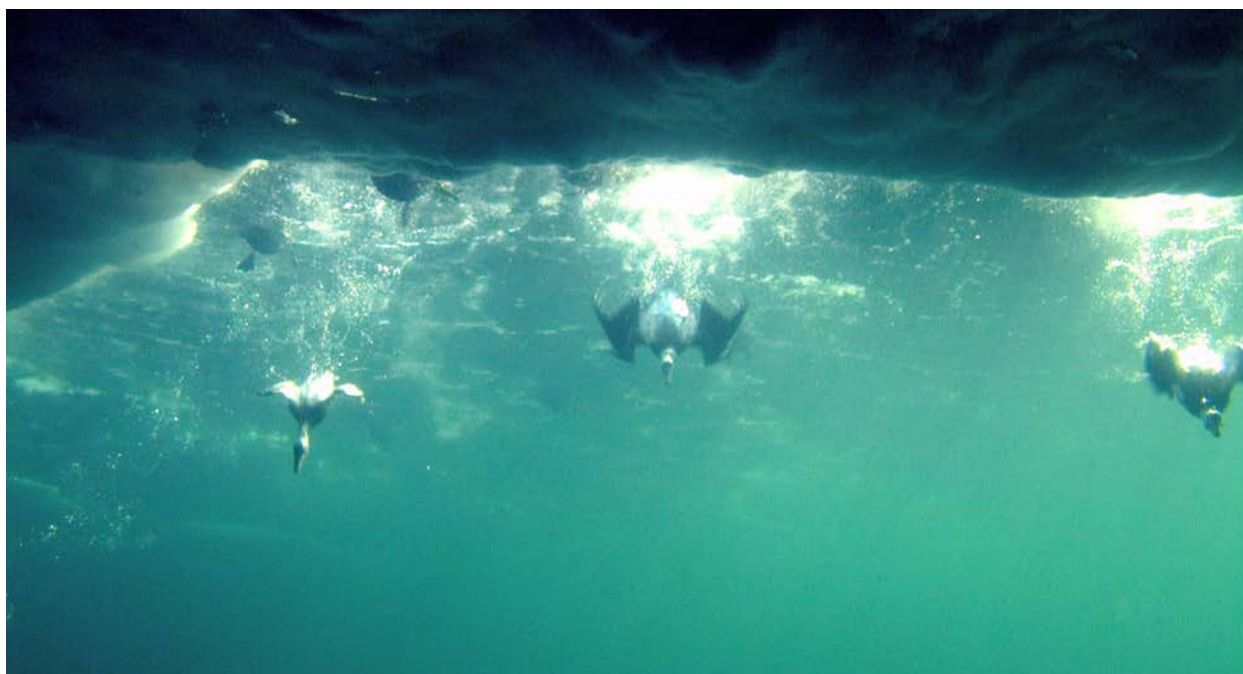5. As a class, complete the Post-discussion Questions (pg. 14).

IMAGE 4 Eiders dive under the sea ice. (J.Heath)

WORKSHEET

Eider ducks at the ice edge have to dive down to the seafloor to get food. Strong ocean currents keep the water from freezing but also increase the difficulty of diving. Underwater video allows researchers to determine how long it takes the ducks to reach the bottom in different current conditions, while depth profilers tell us how deep the water is.

PART 1

1. Watch Dive Video #1 (pg. 4) and record the time it takes for the eider duck to reach the seafloor

   - Distance to bottom: *10 meters*
   - Time to bottom: *~ 7 sec*

2. With the freeze frame from the video, use a protractor to estimate the dive angle of the eider in relation to the surface of the water.
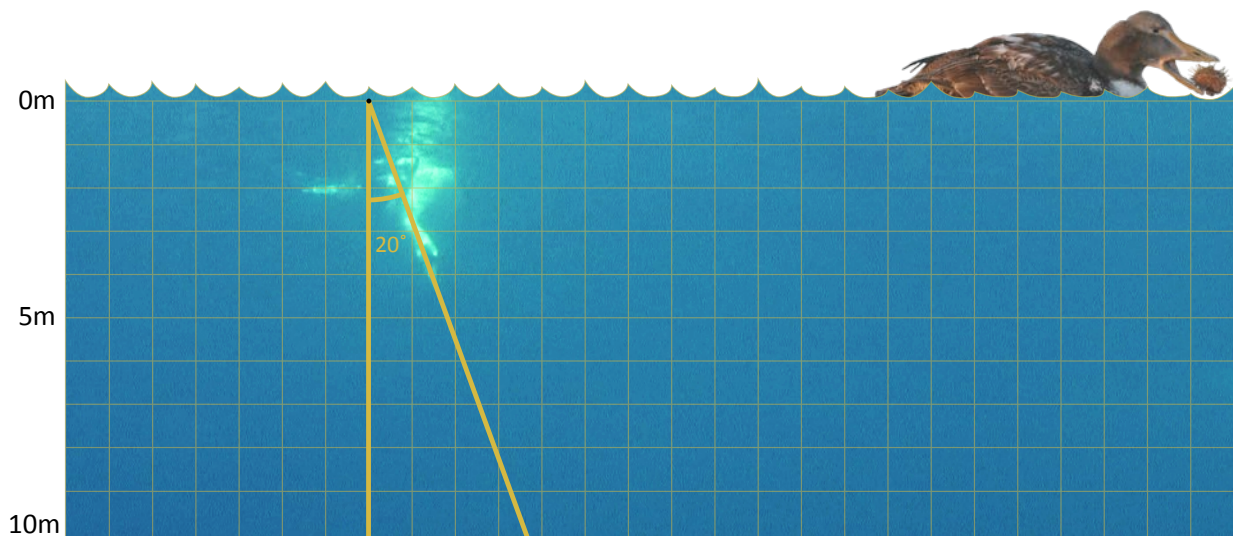
FIGURE 1 Estimate the eider duck's dive angle. (Answer key: the eider dives at approximately 20˚)

3. Using the information you gathered from the dive video, draw a right triangle on *Figure 2* that includes:

   Ⓐ The depth of the water

   Ⓑ The trajectory (path) that the eider takes to reach the bottom, and

   Ⓒ The dive angle

5m

20°

adjacent
(10.00 m)

hypotenuse
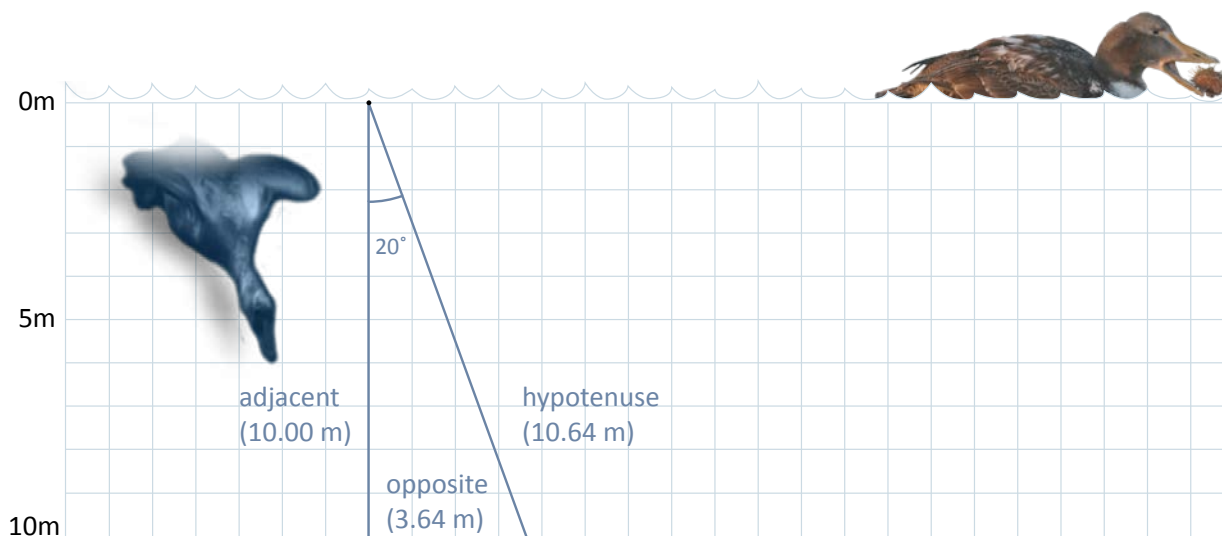(10.64 m)

opposite
(3.64 m)

10m

FIGURE 2 Draw a labeled diagram of the eider ducks dive. (Answer key: 20˚)

4. Use the dive angle and the distance to the seafloor to calculate the actual dive distance (trajectory) the eider duck travels. Use trigonometry to solve the right triangle. Label your diagram on *Figure 2* appropriately with the answer.

$$hyp = \frac{adj}{cos\theta} = \frac{10m}{cos(20°)} = 10.64 \ m$$

5. Using the distance of the dive trajectory and the amount of time it takes the eider to reach the bottom to help you, calculate the velocity (speed) of the diving eider.

$$v_{speed} = \frac{distance}{time} = \frac{10.64 \ m}{7 \ s} = 1.52 \ m/s$$

6. Because you know the depth and trajectory distance, you can now use Pythagorean theorem to find out how far the eider has moved against the current in relation to the sea floor (the 3rd side of the triangle).

$$c^2 = a^2 + b^2$$

$$hyp^2 = adj^2 + opp^2$$

$$opp = \sqrt{hyp^2 - adj^2}$$

$$opp = \sqrt{10.64^2 - 10^2}$$

$$opp = 3.64$$

7. The research team has filmed the same eider diving later in the day at a different place in the polynya. The eider dives at a 25º angle and it takes 10 seconds to reach the bottom. Draw a new diagram and repeat questions 3-6 to determine:

   (A) The dive distance

   (B) Velocity, and

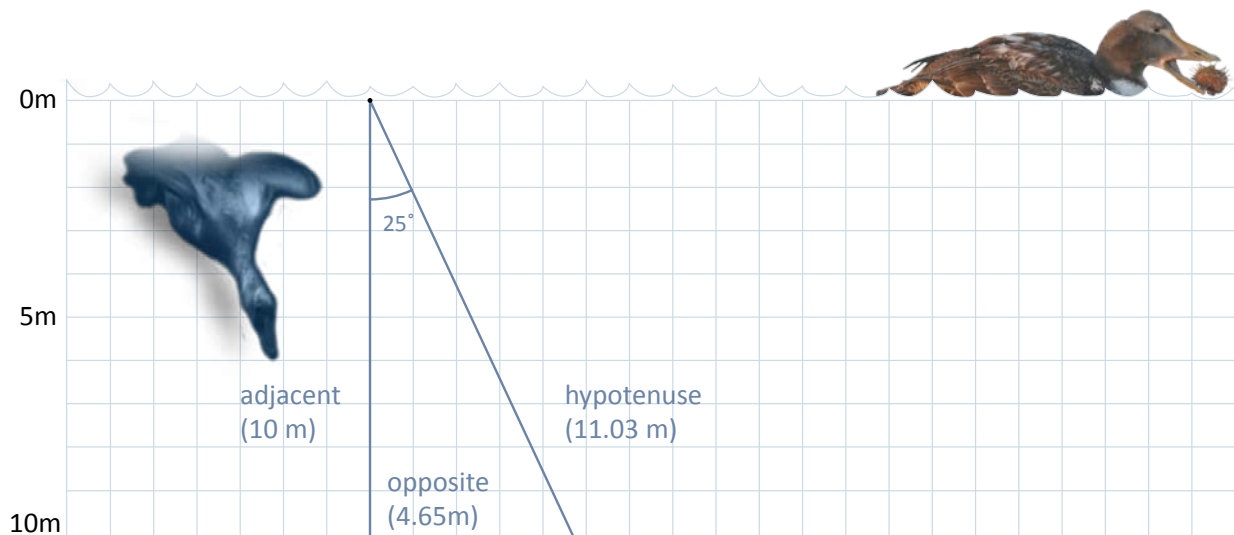   (C) The distance travelled in relation to the sea floor.

FIGURE 3 Draw a labeled diagram of the eider ducks dive. (Answer key for 25˚)

$$hyp = \frac{adj}{cos\theta} = \frac{10m}{cos(25°)} = 11.03 \ m$$

$$v_{speed} = \frac{distance}{time} = \frac{11.03 \ m}{10 \ s} = 1.10 \ m/s$$

$$c^2 = a^2 + b^2$$

$$hyp^2 = adj^2 + opp^2$$

$$opp = \sqrt{hyp^2 - adj^2}$$

$$opp = \sqrt{11.03^2 - 10^2}$$

$$opp = 4.65$$

PART II

Powerful tidal currents keep many polynyas and flaw leads open thereby providing critical habitat for marine birds such as eider ducks. However, currents also work against the birds when they dive to the seafloor in search of food. In very fast currents, the eider ducks get out of the water, rest on the ice edge, and wait for the tide to slacken (slow down). Over a tidal cycle, currents at some polynyas range from 0 m/s to over 1.5 m/s during peak **tidal ebb** (when the tide is going out) or **tidal flood** (when the tide is coming in). This is faster than some rivers!

Eiders swim directly into oncoming currents when they dive. If the current is moving against them at 1.0 m/s, an eider duck has to swim at that same velocity just to stay in once place! The velocity at which an eider duck swims to the bottom is called its observed velocity, the speed at which it moves relative to an observer.

8. Watch the Dive Video #2 (pg. 4). Record both how long it takes the eider duck to reach the bottom and the velocity of the current recorded by the current meter.

    A Dive time: *~ 10 Seconds*

    B Current Velocity: *0.8 m/s*

9. Calculate the observed velocity of the eider as it dives.

$$v_{speed} = \frac{distance}{time} = \frac{10\ m}{10\ s} = 1.0\ m/s$$

10. To help visualize what effect the current has on the eider's dive, draw two arrows (force vectors) indicating the direction and observed velocity of the eider and the direction and velocity of the current.
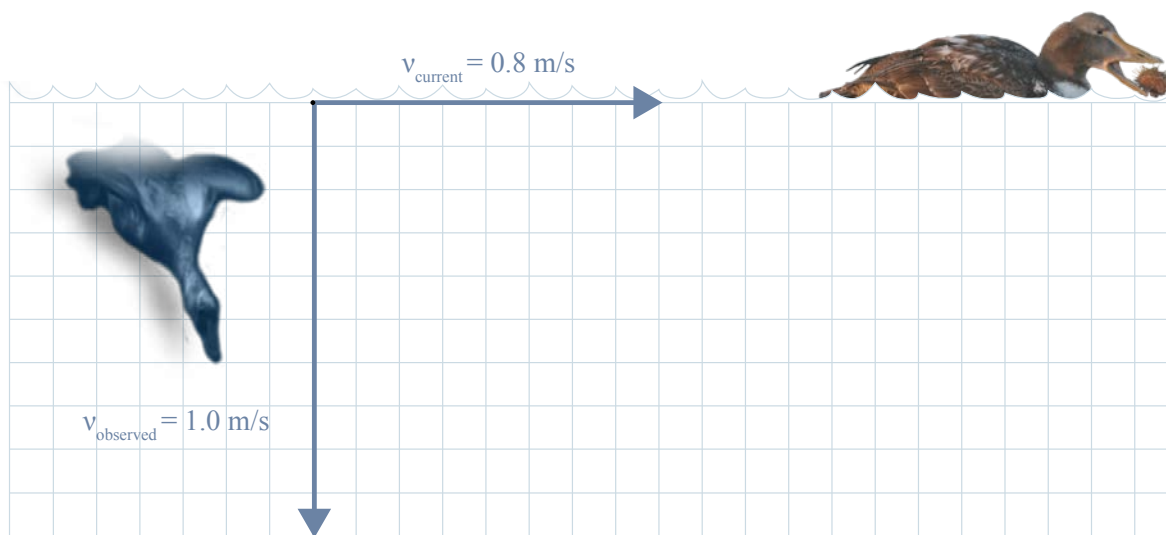

$v_{current} = 0.8$ m/s

$v_{observed} = 1.0$ m/s

FIGURE 4 Draw two force vectors for $V_{observed}$ and $V_{current}$. (Answer key)

To actually reach the bottom, the eider duck can't just swim downwards. If it did, it would be pushed back by the current and might even get pushed under the sea ice. When an eider dives it is both swimming in a downwards direction towards its food at the bottom of the polynya and in a forward direction into the oncoming current. The effective swimming speed of the bird is determined by both the speed at which the duck swims down and the speed of the current.

11. Redraw the force vector arrows from question 2 and using a dotted line, indicate the approximate direction of the combined forces. Label the dashed line $V_{effective}$ for effective velocity.
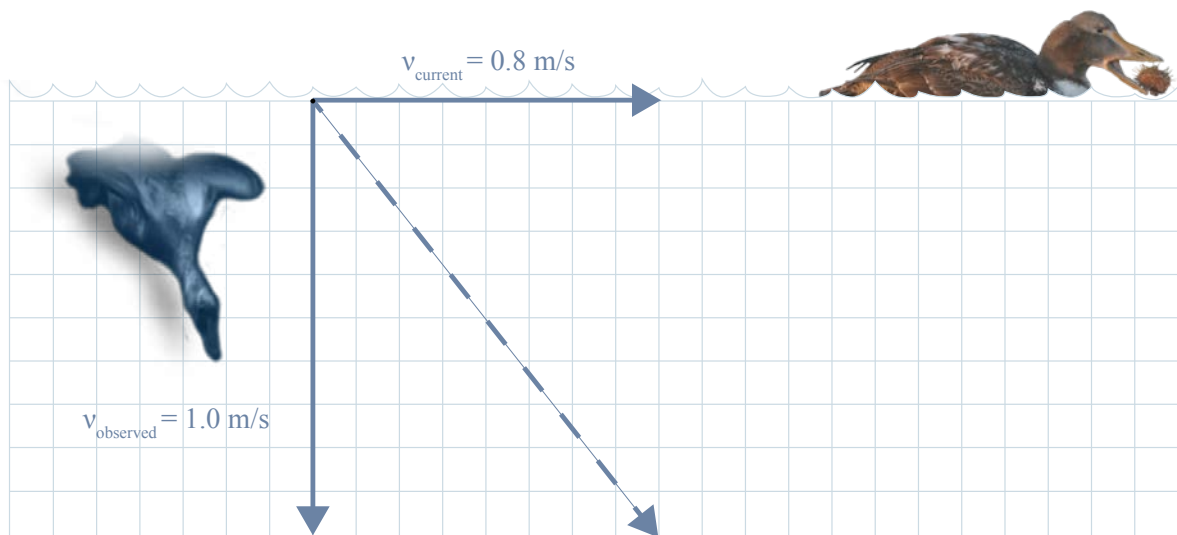

$v_{current} = 0.8$ m/s

$v_{observed} = 1.0$ m/s

FIGURE 5 Draw a force vector diagram with $V_{effective}$. (Answer key)

12. If $V_{observed}$ is the velocity that we recorded from viewing the duck, what does $V_{effective}$ tell us?

It tells us the velocity of the duck that is needed to make it to its destination and overcome the velocity of the current.

13. Would you expect the $V_{effective}$ to be greater or less than the $V_{observed}$? Why?

Both intuitively, and by looking at the length of the vector arrow, students should be able to guess that $V_{effective} > V_{observed}$.

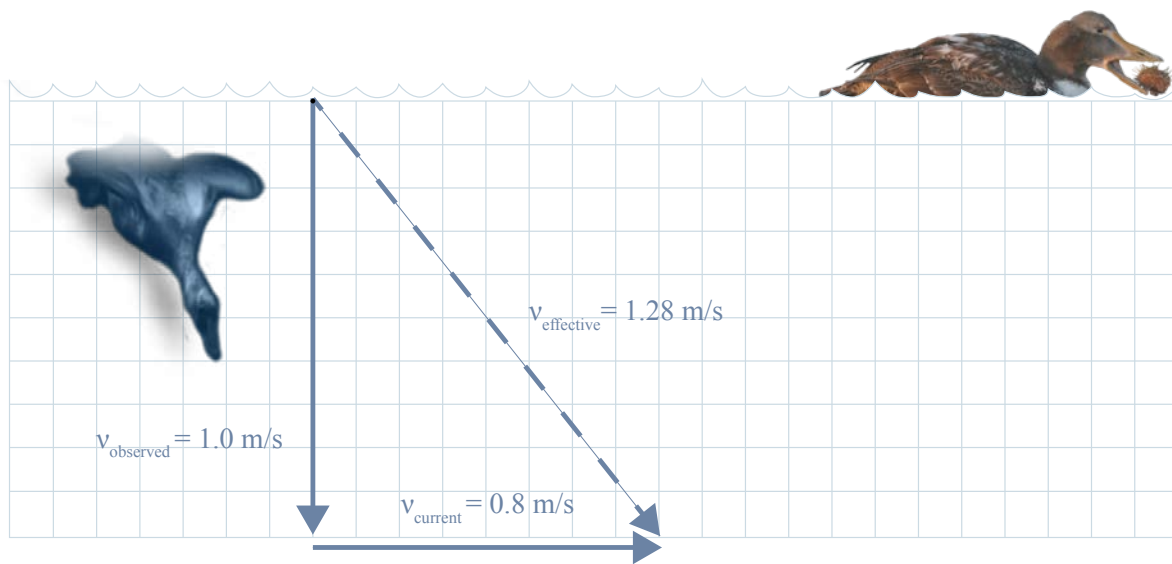14. Now redraw this force vector as a right triangle and solve for $V_{effective}$.

FIGURE 6 Draw a force vector diagram as a right triangle and solve for $V_{effective}$. (Answer key)

$$c^2 = a^2 + b^2$$

$$c = \sqrt{a^2 + b^2}$$

$$hyp = \sqrt{adj^2 + opp^2}$$

$$v_{effective} = \sqrt{v_{observed}^2 + v_{current}^2}$$

$$v_{effective} = \sqrt{1.0^2 + 0.8^2}$$

$$v_{effective} = 1.28 \; m/s$$

Throughout the tidal cycle, even though the strength and speed of the current may change, the effective swim velocity and the rate at which eider ducks flap their wings, remains relatively constant. Thus, when the current increases, the time and the number of times a duck has to flap its wings to get to the bottom increases.

15. Using what you have learned, if the current increased to 1.0 m/s, how long would it take for the eider to reach the bottom? *Hint: you already know the effective velocity.*
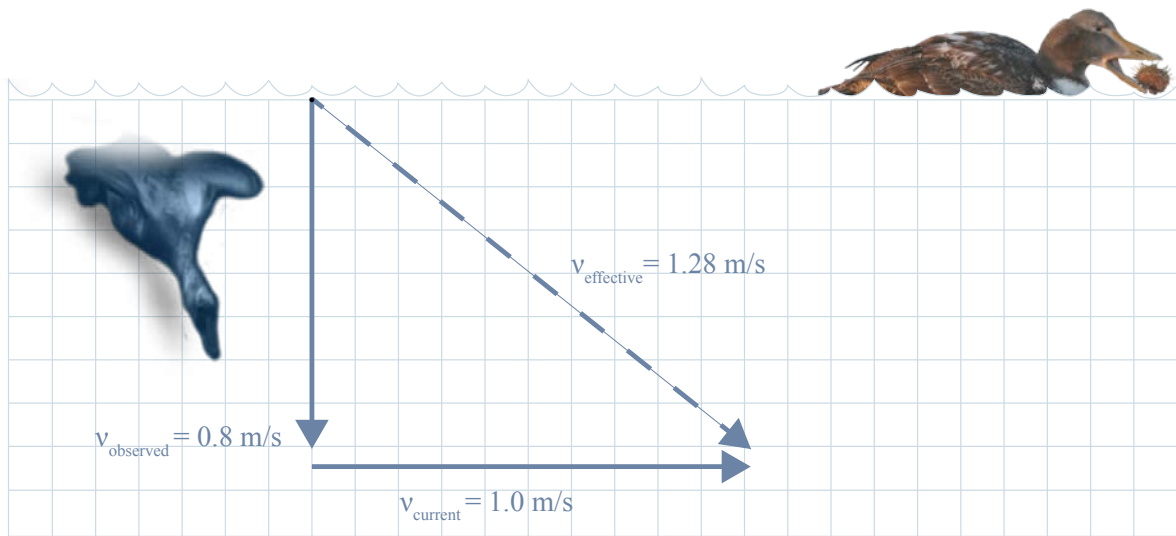

$v_{effective} = 1.28$ m/s

$v_{observed} = 0.8$ m/s

$v_{current} = 1.0$ m/s

FIGURE 7 Redraw the force vectors as the current increased to 1.0 m/s. (Answer key)

$$c^2 = a^2 + b^2$$

$$a^2 = c^2 - b^2$$

$$adj = \sqrt{hyp^2 - opp^2}$$

$$v_{observed} = \sqrt{v_{effective}^2 - v_{current}^2}$$

$$v_{observed} = \sqrt{1.28^2 - 1.0^2}$$

$$v_{observed} = 0.8 \; m/s$$

16. What happens to the observed velocity when the current speed increases and why?

The $V_{observed}$ decreases because when the current speed goes up, the eider duck has to work harder to reach the bottom. This means it goes slower, takes longer and it uses up more energy in the process.

PRE-DISCUSSION QUESTIONS

1. Why would researchers want to investigate the feeding behaviour of eider ducks?

   - *We need to know what they eat and how they obtain food so we can determine how it might impact our fishing and hunting behaviors.*
   - *We can learn something about what happens under the ice, which we can't usually see.*
   - *We need to know the range of conditions the ducks need so we can predict how they might be affected by climate change or other events.*
   - *It can help us make conservation and management decisions.*

2. What are some of the **abiotic**, **ecological**, and **physiological** factors that you think could influence the diving behaviour of eider ducks?

Biotic factors include:

- *Tidal currents*
- *The tidal cycle*
- *Sea ice movement*
- *The freezing and thawing of sea ice*
- *Water temperature*
- *Air temperature*
- *Water depth*

Physiological factors include:

- *How cold the eider duck is*
- *How much energy the eider duck has saved-up*
- *Whether the eider duck is full or is digesting mussels*

Biotic ecological factors include:

- *How many mussels and urchins there are at the bottom of the polynya*
- *Where the mussels and urchins are at the bottom of the polynya*
- *How many other eider ducks are in the polynya*
- *Any predators that might be around the polynya*
- *Physiological factors include:*
- *How cold the eider duck is*

POST-DISCUSSION QUESTIONS

PART I

1. What does changing the dive angle mean for how far the eider dives and where it ends up on the seafloor?

   By increasing the dive angle, it increases the distance and the time required for an eider to reach the seafloor.

2. Why might an eider change the angle at which it dives? What are possible consequences of this change?

   • *It has to swim against strong currents without getting swept away*
   • *Food directly underneath the eider is depleted or less desirable.*

3. Why do we gain from researching how eiders dive?

   It helps us better understand environmental change such as the weaker currents' effects on sea ice ecosystems. It could also help hunters figure out the best time to hunt eiders.

PART II

4. How does walking on a windy day compare to how eider ducks have to dive for food when there is a current?

   It is harder to walk into the wind than to walk with it.

5. Why do eider ducks dive into the current?

   If they didn't dive into the current they would be swept much further away from their desired location on the seafloor.

6. If you were an eider, what factors would you consider when trying to decide how and when to dive to the bottom to eat?

   • *Current strength*
   • *How much food is available? (is the trip worth it)*
   • *How much energy you have to use to make the dive.*

LINKS

▶ **Making Eider Skin Parkas**
See how the traditional Eider parkas were made for our film People of a Feather
https://arcticeider.com/links/dts2

▶ **Eiders Diving Sequences**
Watch eiders dive and hunt under the sea ice
https://arcticeider.com/links/dts3

▶ **Underwater Timelapse of Eider Diving and Urchins**
https://arcticeider.com/links/dts4

▶ **Group of Eider Ducks Diving**
https://arcticeider.com/links/dts5

▶ **Eider Swims Against the Current**
https://arcticeider.com/links/dts6

▶ **Polynya with Eider Timelapse**
Timelapse over the course of a day of eiders diving at a polynya
https://arcticeider.com/links/dts7

SOURCES

Cover photo by J. Heath.

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