INVASION of the ALIEN FISH

A film by Tom Fitz

Classroom Discussion Guide

High School Version (Grades 9-12)

Content created for **Schoolyard Films, Inc.** by Cypress Curriculum Services, LLC

Film Overview

"There is an invasion underway in the western Atlantic. An alien species has moved in, and our native marine habitat is under attack."

Invasion of the Alien Fish focuses on the alarming expansion of the first non-native, invasive marine fish in the western Atlantic—the Indo-Pacific red lionfish. Since its introduction to Florida waters in the 1980's, lionfish have spread like wildfire across much of the Caribbean, Atlantic Coast of the U.S., and the Gulf of Mexico. These beautiful, but unwelcome, predators are eating their way across the region, resulting in devastating harm to already stressed coral reef ecosystems.

With an engaging narrative and striking imagery, this informative 13-minute film profiles researchers, conservationists, and educators as they fulfill their unique roles in the fight against the lionfish invasion. Viewers will follow Mark Albins and Tim Pusack, researchers from Oregon State University, as they study the ecological consequences of the lionfish expansion in the Bahamas. Then at Coral Shores High School, film producer Tom Fitz works with science teacher David Makepeace and his inquisitive students to study lionfish feeding using high-speed cameras. Finally, the film takes viewers to the Reef Environmental Education Foundation's Lionfish Derby in the Florida Keys, where citizens participate in lionfish harvesting, collect specimens for scientific investigation, and enjoy tasty preparations of lionfish filets. *Invasion of the Alien Fish* serves as an excellent discussion starter and entry point for students to learn about not only the invasive lionfish, but also other invasive species currently impacting Florida's unique natural and economic resources.

How to Use This Guide

This guide can be used to supplement study of the Next Generation Sunshine State Science Standards, specifically alongside content such as scientific investigation, the processes and diversity of life, interactions between living organisms and their environments, and the impact of scientific knowledge and technology on communities, cultures and societies.

The "student briefing" provided on pages 4-6 may be distributed to the class prior to viewing the film and read together or individually. The discussion questions on page 7 may be used as springboards to stimulate classroom discussion or as writing prompts. For an extension activity on the topic of population growth of invasive species, see the classroom activity on page 11.

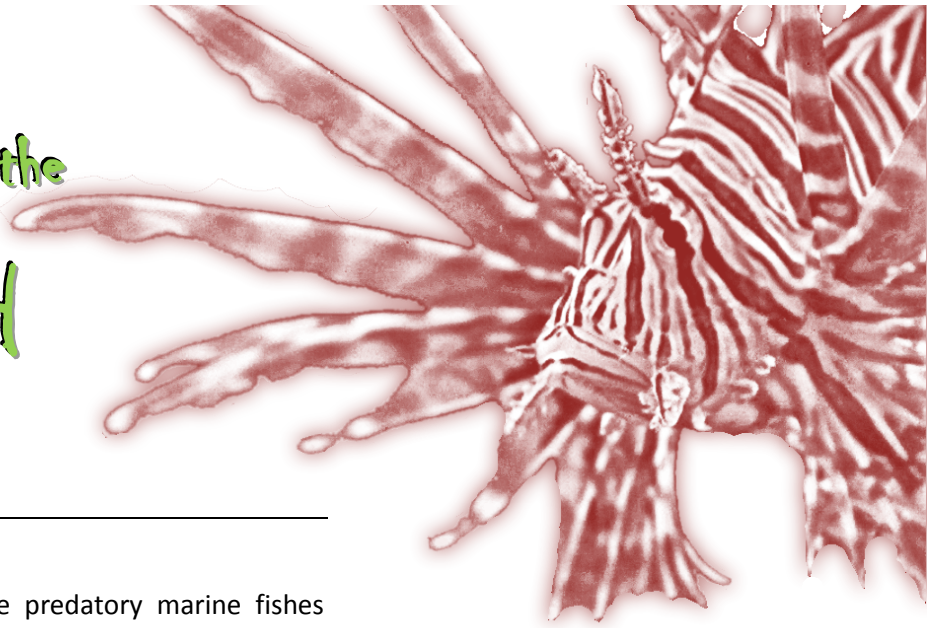
National Standards Correlations

Discussion Guide Element	Unifying Concepts and Processes	Science as Inquiry	Science in Personal and Social Perspectives	Life Science	History and Nature of Science
Discussion Question #1	●			●	
Discussion Question #2	●	●	●	●	●
Discussion Question #3	●		●	●	●
Discussion Question #4			●	●	
Discussion Question #5	●	●	●	●	
Discussion Question #6	●		●	●	
Exploration Activity: Lionfish Mark and Recapture	●	●	●	●	●

Sunshine State Standards Correlations

Discussion Guide Element	Sunshine State Standards			
Discussion Question #1	SC.912.L.17.6	SC.912.L.17.8	SC.912.L.17.11	SC.912.L.17.20
Discussion Question #2	SC.912.L.15.3 SC.912.L.17.8	SC.912.L.17.4 SC.912.L.17.11	SC.912.L.17.6	SC.912.L.17.7
Discussion Question #3	SC.912.L.15.13	SC.912.L.17.5	SC.912.L.17.6	SC.912.L.17.8
Discussion Question #4	SC.912.L.17.7	SC.912.L.17.8	SC.912.L.17.12	
Discussion Question #5	SC.912.L.15.3 SC.912.L.17.11 SC.912.N.2.2	SC.912.L.15.13 SC.912.L.17.12	SC.912.L.17.5 SC.912.L.17.16	SC.912.L.17.8 SC.912.L.17.19
Discussion Question #6	SC.912.L.17.8 SC.912.L.17.15 SC.912.L.17.20	SC.912.L.17.11 SC.912.L.17.16 SC.912.N.2.2	SC.912.L.17.12 SC.912.L.17.17 SC.912.N.4.1	SC.912.L.17.13 SC.912.L.17.18 SC.912.N.4.2
Exploration Activity: Lionfish Mark and Recapture	SC.912.L.17.1 SC.912.N.4.1	SC.912.L.17.5	SC.912.N.1.6	SC.912.N.3.5

INVASION of the ALIEN FISH



Student Briefing

Lionfish (*Pterois volitans* and *P. miles*) are predatory marine fishes native to the Indian and Pacific oceans. These tropical *piscivores* have striking reddish-brown and white bands and elegant elongated fin spines. But these spines are not just for show-- they contain a powerful neurotoxin. When a lionfish feels threatened, it will extend its spines and deliver an extremely painful sting to its antagonist. This potent defense mechanism is the likely reason that lionfish have few natural predators.

Reports of lionfish in Florida coastal waters began in the mid-1980's. Scientists were immediately concerned that lionfish may thrive in Florida's marine waters and disturb native coral reef ecosystems. Since then, lionfish have spread throughout the region at an alarming rate. Lionfish are now reported throughout the Caribbean Sea, the eastern Gulf of Mexico, and along the U.S. Atlantic Coast. In some areas, lionfish reach exceed 400 fish per hectare (or roughly 990 fish per acre).

Another notable trait of lionfish is their huge appetite. This voracious predator is known to prey on over 40 species of fish and crustacean species in the Bahamas. And lionfish eat these species in large numbers! It is reported that a lionfish's gut can expand to nearly 30 times its initial volume in order to fit a large meal.

The distribution of lionfish in the western Atlantic Ocean.
Source: U.S. Geological Survey. 2011

Lionfish are the first non-native marine finfish to establish in Florida waters, but the story of biological invaders from other lands (and oceans) is hardly new. Modern commerce has led to the spread of *non-indigenous species* to most regions of the world. Cargo ships, fast trains, and airliners have removed the barriers to species movements once created by oceans, mountain ranges, and other obstacles. Many relocated species find their new homes inhospitable and are unable to establish populations. But many species manage to find a *niche* in their new land. Some of these successful colonizers become what biologists call *invasive*—that is, their presence in the new environment causes economic or environmental harm or harm to human health. Well-known examples of *invasive species* in the U.S. include the Burmese

python (Florida), zebra mussel (Great Lakes), Indian mongoose (Hawaii), and water hyacinth (throughout the U.S.).

You may ask, "Why do some species become invasive while others do not?" The answer is often complicated, involving many ecological factors, but most invaders are successful because they no longer have pressure from natural enemies. These natural enemies may be predators, parasites, or diseases, which keep the species' population in check "back home." If new predators or diseases do not assume this population regulation role in the invaded environment, the species can develop a significant advantage over other species. This leads to explosive population growth and often devastating consequences to ecosystems.

Frequently Asked Questions

How did lionfish establish in the western Atlantic Ocean?

Lionfish are prized pets by aquarium hobbyists worldwide. Unfortunately, intentional or accidental releases of lionfish in the U.S. led to the establishment of this species in Florida waters during the mid-1980s. Since then, wild lionfish populations have rapidly spread along the southeastern U.S. coastline and throughout the Caribbean Sea.

Why do scientists worry about the spread of lionfish?

As a *generalist* predator, lionfish pose a serious threat to many reef fish populations, both through direct *predation* and *competition* with native predators for food. Ongoing reef monitoring programs are reporting huge declines of native reef fish soon after the arrival of lionfish. Affected species include many *teleosts* (ray-finned fish), which are important to reef diversity and are prey for economically important fish.

How are lionfish able to flourish in the western Atlantic Ocean?

Like many aggressive invaders, lionfish have survival advantages in their new environment that they do not have in their native environment. Scientists do not fully understand what factors are involved, but possible reasons for the success of lionfish include the absence of predators, diseases, parasites, and competitors. For example, recreational and commercial fishing has severely depleted many native predator populations (e.g., snappers, groupers). It is possible that a lack of *competition* from other *piscivores* has facilitated the explosion of lionfish.

Internet Resources

More on the Lionfish

NOAA Lionfish Assessment
http://coastalscience.noaa.gov/documents/lionfish_%20ia2009.pdf

USGS Lionfish Site
http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=963

Reef Environmental Education Foundation
www.reef.org/lionfish/

USGS Lionfish reporting Site
http://nas.er.usgs.gov/SightingReport.aspx

Invasive Species

National Invasive Species Information Center
www.invasivespeciesinfo.gov/index.shtml

Global Invasive Species Database
http://www.issg.org/database/welcome/

Responsible Pet Ownership

HABITATITUDE
http://habitattitude.net/

Don't Let It Loose
www.nps.gov/ever/forteachers/dlil.htm

Florida Pet Amnesty Program
http://myfwc.com/wildlifehabitats/nonnatives/

What is being done to stop the spread of lionfish?

Unfortunately, control options are extremely limited. The broad geographic distribution and large numbers of lionfish make eradication of this species highly unlikely. However, localized control efforts, particularly in shallow waters, may be practical. Government agencies, academic institutions, and other research groups are actively investigating lionfish management tools and strategies, including trapping, harvesting by divers, and creating fisheries. Public outreach programs are also underway to educate the public about the problem of lionfish and other *invasive species*.

How can I help?

One of the best things you can do is be a responsible pet owner. Carefully research an animal before purchasing it to be sure that you can care for it for its entire life. How big will it get? What is the animal's temperament? How much will it cost to care for? These are all important questions to ask before purchasing a pet. Most importantly, never release your exotic pet into the wild. Exotic pets usually cannot survive in the wild and will probably suffer greatly as they struggle to stay alive. The small number of exotic pets that do survive may establish populations and eventually cause harm to the environment. Instead of releasing your pet, try to find it a new home. There are rescue groups for many types of pets, and some pet retailers allow you to return your animal or accept it as a donation. Also, the Florida Fish & Wildlife Conservation Commission holds pet amnesty days throughout Florida each year. Visit the FWC website to find the next pet amnesty day near you. Another way to help is to report any sightings of lionfish. The U.S. Geologic Survey maintains a website for reporting *non-indigenous species* (see *Internet Resources* box).

Glossary of Key Terms

COMPETITION: a contest between two or more species for a limited environmental resource

GENERALIST: a species that can survive in a variety of habitat conditions or that consumes food from multiple sources

INVASIVE SPECIES: a non-native species that negatively affects the habitats they invade either economically or environmentally

NEUROTOXIN: a poison that acts on nerve cells

NICHE: an organism's role, function, or position in an ecosystem

NON-INDIGENOUS species: a species living outside its native range as a result of human activity. Synonyms: non-native, exotic, and alien.

PISCIVORE: a carnivorous animal that mostly consumes fish

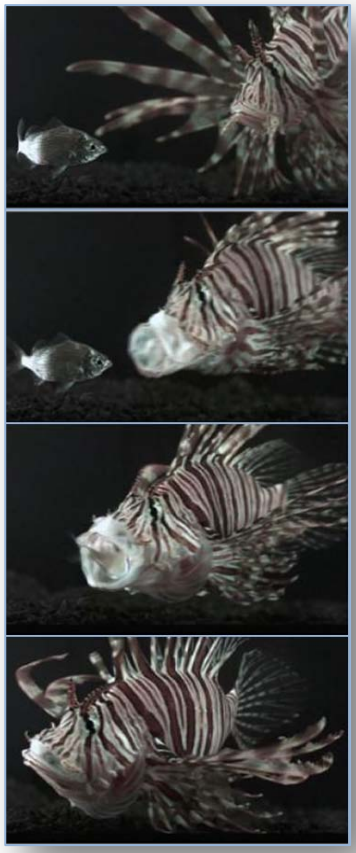
TELEOST: any member of the large and diverse group of ray-finned fishes. Teleosts are characterized by the presence of a symmetrically lobed tail.

Discussion Questions/Writing Prompts

Use the following questions to stimulate classroom discussion or as writing prompts. Either way, the goal is to foster discussion on the level of synthesis and analysis. Below each question, you will find supporting information and recommendations to facilitate classroom discussion.

1. **There are many terms used to describe organisms that become established in new areas--invasive, exotic, non-native, non-indigenous, and alien. What does it mean for a species to be invasive? Is this term necessarily synonymous with non-native or exotic?**

   - *Explore, through discussion, the differences in these and other terms that refer to an organism's non-native status. Widely accepted definitions are:*
     - *i. Non-native, non-indigenous, exotic, and alien are all terms describing species that are introduced to an area where they do not occur naturally.*
     - *ii. An invasive species is a non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human health.*
   - *Students should understand that only those non-native species that cause economic or environmental harm are considered invasive and that only a very small percentage of established non-native species are known to cause harm.*
   - *Ask students what they know about impacts from invasive species. Ask for examples in three impact areas—environmental, economic, and human safety. (see Table 1)*
   - *Point out to students that many non-native species have been established in Florida for decades without causing significant harm to the environment or the economy. For example, the non-native cattle egret (Bubulcus ibis) has spread throughout the southeastern U.S., but since it feeds on insects flushed by large ungulates and only enters aquatic habitats to nest, there is little evidence that this species impacts native wading birds*[1]
   - *Ask students to consider whether naturalized species should eventually be classified as native. As Michael Pollan, writer in New York Times Magazine ponders, "Shouldn't there be a statute of limitations on the alien status of introduced species?"*[2]



[1] Global Invasive Species Database (www.issg.org)

[2] Michael Pollan, "Against Nativism," *New York Times Magazine.* (1994) May 15: 52–55

2. **The film points out that scientists consider lionfish to be a threat to reef ecosystems in the Atlantic Ocean and Caribbean Sea. What are some of the problems caused by lionfish?**

- ***Predation****—students should recognize that predation on coral reef fishes is the most direct impact of lionfish. Make sure students understand that lionfish prey on a wide-variety of small-bodied fish. According to one study, lionfish feed on 41 species of coral reef fish*[3]*. As such, lionfish can be classified as generalist predators.*
- ***Fisheries****—two economically-important species that are preyed upon by lionfish are the yellowtail snapper and Nassau grouper. In addition to direct predation, lionfish compete with these species for prey. Therefore, it is likely that lionfish will negatively affect these fisheries.*
- ***Diversity****—as a generalist predator, lionfish are capable of reducing or locally eradicating many species of fish. Such changes to native fish predation rates would have a dramatic negative effect on biological diversity of coral reef ecosystems.*
- ***Community structure****—since lionfish prey on many herbivorous species, coral reefs can shift to algae-dominated reefs in the absence of fish that normally maintain low algae levels on coral.*[4]

Table1. Examples of invasive species impacts in the United States.

Environmental Impacts	
Extinction	Introduction of chestnut blight caused the extinction of many insect species.
Diversity	Melaleuca tree converts diverse Everglades marsh to melaleuca forest with very low plant and animal diversity.
Competition	Cuban tree frog out-competes most native frogs throughout Florida.
Predation	Introduction of the mongoose led to huge declines in Hawaiian birds.
Habitat Loss	Roots of Australian pines limit sea turtle nesting habitat in Florida.
Economic Impacts	
Fisheries	Loss or reduction of fisheries by quagga mussels in Great Lakes Region
Livestock	Lantana (shrub) poisons cattle on rangeland.
Navigation	Water hyacinth and water lettuce clog canals, rivers, lakes and disrupt watercraft navigation.
Crop Production	Non-indigenous weeds cost U.S. agriculture an estimated $3 billion annually.
Health and Safety	
Disease	The Gambian pouched rat introduced monkey pox in the U.S.
Safety	Schools of Asian carp create boating hazards when they leap out of the water.

[3] James A. Morris Jr. and John L. Akins, "Feeding Ecology of Invasive Lionfish (*Pterois volitans*) in the Bahamian Archipelago," Environ Biol Fish (2009) 86:389–398.

[4] Michael P. Lesser and Marc Slattery, "Phase Shift to Algal Dominated Communities at Mesophotic Depths Associated with Lionfish (Pterois Volitans) Invasion on a Bahamian Coral Reef " Biological Invasions (2011) 13:1855–1868.

3. **What are common characteristics of invasive species?**

- *Ask students to consider characteristics of species that would make them more likely to be invasive in a new environment.*
- *Potential responses include the following:*
    i. *High reproductive rate*
    ii. *Lack of predators, parasites, and pathogens in new environment*
    iii. *Generalist feeding behavior*
    iv. *Rapid growth rate*
    v. *Wide tolerance for habitat conditions*
- *Ask students which of the characteristics would apply to both plants and animals.*

4. **What are other examples of non-indigenous species currently established in Florida?**

- *Ask students what other non-native, invasive species they are aware of. As different species are discussed, ask students what they know about the species' distribution in Florida, the habitats they occupy, and the environmental and economic impacts caused by the species. Table 2 includes a selection of well-known invasive species established in Florida. For more information on Florida's non-indigenous species, visit www.EDDmaps.org, www.FLEPPC.org, and www.myfwc.com.*

5. **What do you think of the argument that non-indigenous species benefit the environment by increasing biodiversity?**

- *Ask students to either defend or dispute this argument about the role of non-indigenous species in promoting diversity.*
    i. *Diversity will generally increase as new species establish in an ecosystem. With increased diversity, we might expect more stability and resilience in the ecosystem. There may be new interactions between species that have a net positive outcome.*
    ii. *This diversity effect of new species introductions is only positive when the new species is not invasive. An invasive species will displace native species or alter import ecosystem functions (e.g., fire behavior). Eventually diversity will decline in an ecosystem infested with invasive species.*

- *Ask students if native ecosystems should be protected from non-indigenous species if only to preserve the unique ecosystems that existed prior to the relatively recent increase in human-caused species introductions.*

Table 2. Selected invasive, non-indigenous species currently established in Florida.

Common Name	Scientific Name	Type
Brazilian Pepper	*Schinus terebinthifolius*	Plant
Cogongrass	*Imperata cylindrica*	Plant
Hydrilla	*Hydrilla verticillata*	Plant
Melaleuca	*Melaleuca quinquefolia*	Plant
Old World Climbing Fern	*Lygodium microphyllum*	Plant
Water Hyacinth	*Eichhornia crassipes*	Plant
Cane Toad	*Rhinella marina*	Amphibian
Cuban Treefrog	*Osteopilus septentrionalis*	Amphibian
Sacred Ibis	*Threskiornis aethiopicus*	Bird
Mayan cichlid	*Cichlasoma urophthalma*	Fish
Asian Tiger Mosquito	*Aedes albopictus*	Insect
Redbay Ambrosia Beetle	*Xyleborus glabratus*	Insect
Feral Pig	*Sus scrofa*	Mammal
Gambian Pouched Rat	*Cricetomys gambianus*	Mammal
Green Mussel	*Perna viridis*	Mollusk
Island Applesnail	*Pomacea insularum*	Mollusk
Black and White Tegu	*Tupinambis merianae*	Reptile
Burmese Python	*Python molurus ssp. bivittatus*	Reptile
Nile Monitor	*Varanus niloticus*	Reptile
Red-eared Slider	*Trachemys scritpa elegans*	Reptile

6. **Given the frequency of new biological invasions each year, many argue that governments need to do more to protect our native ecosystems. Do you think that federal and state governments should do more? Why or why not?**

- *Ask students what they already know about the government's role in regulating the importation and possession of organisms in the United States*
  - i. *Discuss the federal role of regulating importation and inter-state commerce. Numerous laws are in place to prevent the importation of species known to be harmful. These regulations focus on protecting human health, agriculture, and natural resources. See www.aphis.usda.gov for more information.*
  - ii. *State governments also have authority to regulate the importation and possession of organisms within their jurisdiction. For example, it is now illegal to possess the Burmese python in Florida without a special permit.*

- *Ask students to discuss the costs and benefits of restricting the importation of non-indigenous species. Is an ounce of prevention worth a pound of cure when it comes to invasive species?*
  - i. *Prompt students to consider economic impacts of reducing availability of plants and animals in the pet and ornamental plant industry.*
  - ii. *The total costs of invasive species in the United States are estimated in one study to surpass $100 billion each year.*[5]
  - iii. *Successfully eradicating a species after it has already established is very costly and usually an unachievable goal. For this reason, conservationists argue that government regulators should err on the side of caution and aggressively prohibit importation of organisms that are predicted to become invasive.*
  - iv. *But predicting which species will be invasive is an imprecise science and the exotic pet and ornamental plant industries generate hundreds of billions in revenue each year. Is it fair to restrict these industries in order to prevent biological invasions that are not certain to happen?*

[5] David Pimentel, Rodolfo Zuniga, Doug Morrison. 2005. "Update on the environmental and economic costs associated with alien-invasive species in the United States." Ecological Economics 53(3) 273-288.

Exploration Activity

Estimating Lionfish Populations--A Mark and Recapture Simulation

TEACHER'S GUIDE

This activity is a modification of the popular population estimation simulation using the mark and recapture of beans. In this version of the activity, students will use dry pasta to conduct a desktop population count of "lionfish" on a Florida Keys coral reef. Students will learn the basic principles of the mark and recapture monitoring method, utilize skills in basic statistical calculations, and learn how sample size affects the accuracy and precision of a population estimate. Follow-up questions will allow students to consider the reasons scientists conduct monitoring.

Materials:

Each student group will need:

- 1/2 cup small pasta shells (roughly 100 shells)
- 1 small cup or small paper bag
- black marker
- calculator
- data sheet

Background Information:

Scientists commonly use sampling plots or aerial imagery to monitor plants. With only rare exceptions, plants "cooperate" in monitoring programs—they patiently sit still while the scientist takes measurements. But how does one monitor organisms that move around and almost always run and hide from well-meaning field biologists?

Wildlife ecologists devised the mark and recapture method to estimate population size. The concept of the method concerns the probability of catching an individual in a population twice and how this probability of recapture relates to the actual population. Mark and Recapture monitoring involves the following steps: 1) capturing a sample of the population, 2) marking these individuals with unique identifiers (e.g., tags), 3) releasing the captured animals to redistribute in the population, and 4) re-sampling the population to determine the number of recaptures. Using mathematical models, the researcher can then calculate an estimate of the true population.

A simulation like this provides an excellent, interactive opportunity to emphasize Sunshine State Standards at all levels surrounding the big idea "The Practice of Science." It can be used to discuss method, scientific reasoning, how and why different groups got different results, etc. Teachers can use the discussion questions (and even create additional inquiry-based questions) with this activity to meet the individual needs of a variety of students and classroom settings.

Estimating Lionfish Populations--A Mark and Recapture Simulation

STUDENT LAB SHEET

Purpose: In this activity, you will conduct a classroom simulation of a monitoring program for lionfish occupying a coral reef system in the Florida Keys. Your objectives are to:

a. estimate the number of lionfish occupying a reef system in the Florida Keys
b. determine the effect of sample size on population estimation error

Background: Scuba divers and anglers have reported a troubling increase in the invasive lionfish on several coral reefs near the Florida Keys in recent months. As a state biologist, you need to verify that these observations are accurate and then investigate possible management actions to help limit the impact of this invasion. This activity will deal with your first step—estimate the current population size. This will establish an estimated baseline population, which you can compare to future population estimates to determine whether an increasing trend is present.

How can you determine the number of lionfish on a reef? Obviously, capturing every lionfish on the reef would be very costly, time consuming, and disruptive to the sensitive reef ecosystem. Wildlife biologists use a sampling technique known as **Mark and Recapture** to *estimate* the population size. Here is how it works. Biologists place live traps in the study area and capture a certain number of animals. All captured animals are marked with an identification tag, and then released. After a period of time, the biologists repeat the trapping activity and 1) count the total number of captured animals and 2) make note of how many were previously caught (have ID tags). With these data, biologists can calculate the estimated population size.

Calculations: The mathematical formula for estimating the lionfish population is:

$$\frac{\boldsymbol{R}}{\boldsymbol{M}} = \frac{\boldsymbol{C}}{\boldsymbol{X}}$$

X = Estimate of total lionfish population
M = # lionfish captured and marked during first sample
C = # lionfish captured in second sample
R = # lionfish captured in first sample that were recaptured in second sample

If we solve for the estimated population size, X:

$$\boldsymbol{X} = \frac{\boldsymbol{MC}}{\boldsymbol{R}}$$

Procedure:

a. Collect materials. Each student group will need

- 1/2 cup small pasta shells (roughly 100 shells)
- 1 small cup or small paper bag
- black marker
- calculator
- data sheet

b. Place approximately 1/2 cup (approx. 125 mL) of shells in your cup. The cup represents the coral reef and the shells represent ALL lionfish currently living on the reef.

Conduct 1st Sampling Event:

c. Remove 20 "lionfish" from the reef by removing them from the cup. These represent lionfish captured on the reef during your first sampling event. This number is already recorded under *First Sample Total (M)* on the data sheet.

d. Mark each of these captured "lionfish" with a marker.

e. Release the marked "lionfish" back to the "reef" by placing the shells back into the cup.

f. Gently, but thoroughly, mix the marked lionfish with the other lionfish on the reef.

Conduct 2nd Sampling Event:

g. Randomly remove a second small handful of lionfish from the cup. It is important to pull the sample randomly (e.g. close your eyes and remove shells or slowly pour shells into hand).

h. Record the number of captured lionfish under *Second Sample Total (C)* on the data sheet.

i. How many lionfish did you recapture? Count the number of lionfish in this sample that were recaptured from the first sampling event (lionfish with marks). Record this under *Total Recaptured (R)*.

j. Now count all lionfish on the reef (including the lionfish from your second sample) and record under *Actual Population (P)*. This is the actual population of lionfish on the reef system.

Tally Results and Analyze

k. All groups now report their results for *M*, *C*, and *R* to the class. Each team should record the other groups' data in their own data sheet.

l. Calculate the estimated population size (*X*) and percent difference from the actual population (*% Difference*) for all groups' data.

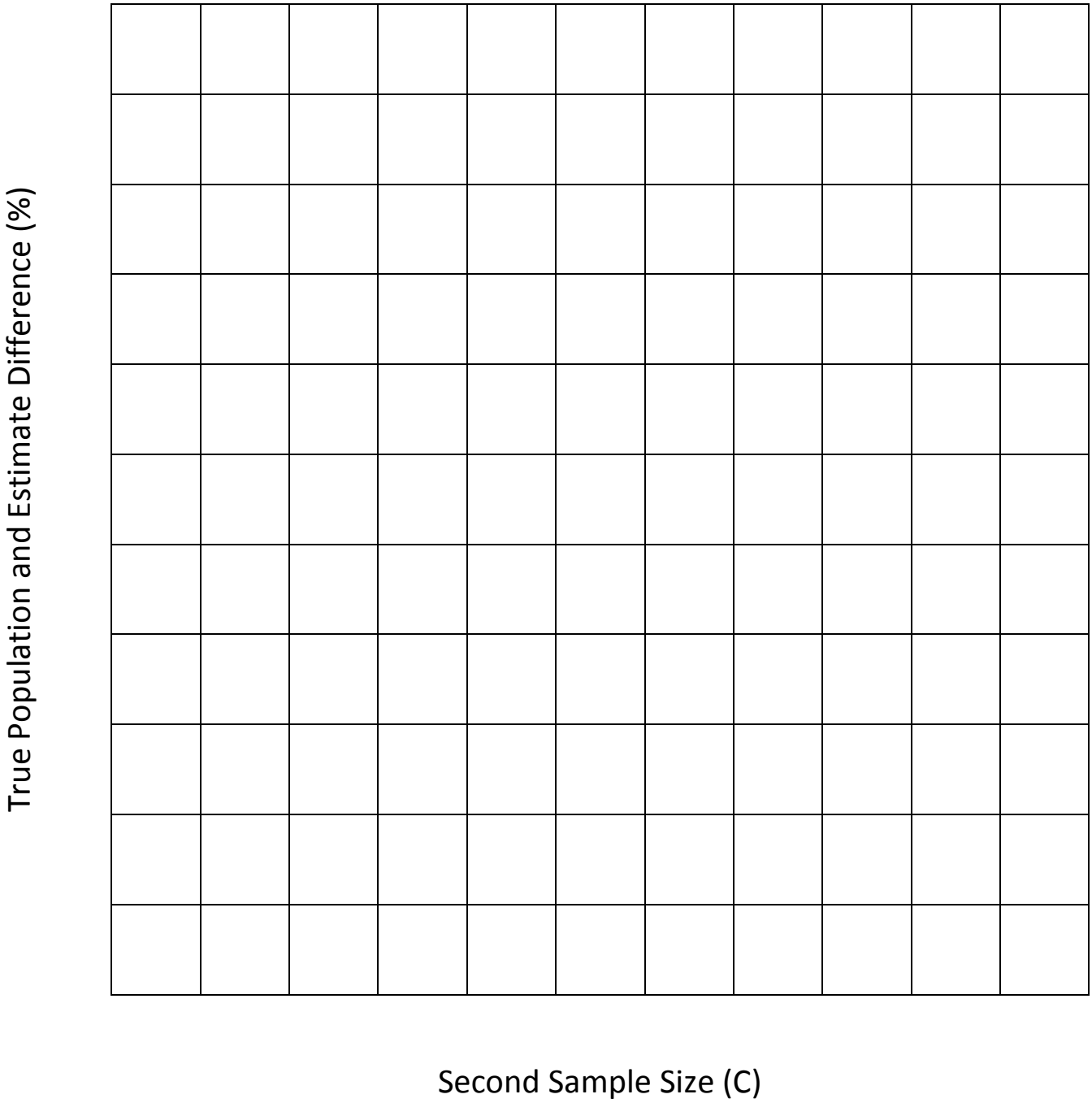
m. What is the effect of sample size on the accuracy of population estimates? Make a scatter plot of Estimated Population (X) and percent difference from the actual population (*% Difference*) and draw a best-fit line through the data points.

Lionfish Mark & Capture Simulation: Data Sheet **Student Name:_____**

Group	*First Sample Total (M)*	*Second Sample Total (C)*	*Total Recaptured (R)*	*Estimated Population (X)* $\frac{M \times C}{R}$	*Actual Population (P)*	% Difference $\frac{X-P}{P} \times 100$
1	20					
2	20					
3	20					
4	20					
5	20					
6	20					
7	20					
8	20					
9	20					
10	20					
11	20					
12	20					
13	20					
14	20					
15	20					
16	20					
17	20					
18	20					
19	20					
20	20					
					Sum % Differences	
					÷ Number of Groups	
					= Average % Difference	

Student Name:_____

Relationship between Sample Size and Estimation Accuracy in a Mark and Recapture Simulation



Lionfish Mark & Capture Simulation **Student Name:_____**

Discussion Questions

1. How did your estimate compare with the actual population size? Did you over-estimate or under-estimate the population?

   _____
   _____
   _____
   _____

2. Was there a lot of variability in the accuracy of estimates among groups?

   _____
   _____

3. How did the average difference between the estimate and real population value compare to your groups alone? What does this suggest about the number of sample events that are necessary for accurate estimates?

   _____
   _____
   _____
   _____

4. Were you able to detect a relationship between sample size and estimation accuracy?

   _____
   _____

5. What other factors might affect the accuracy of the estimate?

   _____
   _____
   _____
   _____

6. Does this seem like an effective method for monitoring lionfish populations at the coral reef? Why not simply count all the lionfish you see while snorkeling?

_____

_____

_____

_____

_____

7. Did this mark and recapture exercise simulate an experiment or an observational study? How can you tell?

_____

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8. What can this data tell us about the causes of changes in the population over time?

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