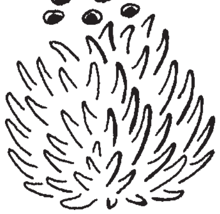

Marine Unit 5

Marine Management

Overview

Since the time of the early Hawaiians, people have been making rules governing the use of the ocean and marine life. Some of these are designed to protect species that are threatened by human actions or that are important to humans but declining in numbers. This unit introduces students to some efforts underway to provide scientific data for use in reef and fishery management. They also learn about some of the ways in which people attempt to protect and restore populations of endangered marine species and design a study to provide more information about changes in fish abundance in the ʻĀhihi-Kīnaʻu Natural Area Reserve.

Length of Entire Unit

Three class periods plus optional in-class time for work on study design (Activity #3) and research projects and presentations (Activity #4)

Unit Focus Questions

1) What are some distinguishing biological and behavioral characteristics of Hawaiian reef animals that are gathered or fished for by people?

2) What are the potential impacts of collecting aquarium fish from Hawaiian reefs?

3) How do scientists conduct studies to monitor and assess these types of impacts?

4) What are some approaches to protecting Hawaiian marine species?

Unit at a Glance

Activity #1
"Weren't There More of Us?" Game

Students play a game to learn about Hawaiian reef animals and regulations intended to protect them.

Length
One class period

Prerequisite Activity
None

Objectives
- Identify Hawaiian reef animals that are valued by humans, distinguishing features of their biology and natural history, and how they are protected under Hawai'i state regulations.

DOE Grades 9-12 Science Standards and Benchmarks
RELATING THE NATURE OF SCIENCE TO TECHNOLOGY: Students use the problem-solving process to address current issues involving human adaptation in the environment.
- Evaluate alternative solutions for effectiveness based on appropriate criteria.

Activity #2
Impacts of Aquarium Fish Collecting on Coral Reefs

Students read a study on the impact of aquarium fish collecting and interpret data from that study.

Length
One class period, preceded by homework

Prerequisite Activity
None

Objectives
- Describe concerns about collecting fish from Hawaiian coral reefs for the aquarium fish trade.
- Interpret data produced by a study on the impact of aquarium fish collecting.
- Identify key elements of the design of the aquarium fish-collecting study.

DOE Grades 9-12 Science Standards and Benchmarks
DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.
- Formulate scientific explanations and conclusions and models using logic and evidence.

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF SCIENCE: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.
- QUESTIONING: Ask questions to clarify or validate purpose, perspective, assumptions, interpretations, and implications of a problem, situation, or solution.

Activity #3
Design a Monitoring Study

Using research design principles learned from the aquarium fish-collecting study, students design their own marine-monitoring study.

Length
One class period, preceded by homework

Prerequisite Activity
Activity #2 "Impacts of Aquarium Fish Collecting on Coral Reefs"

Objectives
- Design a study to monitor the effectiveness of a specific marine protected area.

DOE Grades 9-12 Science Standards and Benchmarks
DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.
- Develop and clarify questions and hypotheses that guide scientific investigations.
- Design and conduct scientific investigations to test hypotheses. (Activity meets the design component of this benchmark.)

Activity #4
Marine-Management Research Projects

Students undertake research projects on marine-management topics of their choosing.

Length
Research time, with optional in-class presentations

Prerequisite Activity
None

Objectives
- Develop a research report on a topic related to marine management on Maui and across the state.

DOE Grades 9-12 Science Standards and Benchmarks
LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF SCIENCE: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.
- SELF-DIRECTED: Use research techniques and a variety of resources to complete a report on a project of one's choice.

Enrichment Ideas

- Obtain copies of current Hawai'i state fishing regulations and find out whether fishing regulations have changed for any of the species in the "Weren't There More of Us?" game. Fishing regulations are available from the Hawai'i Department of Land and Natural Resources, Division of Aquatic Resources.

- Download and print descriptions of threatened and endangered Hawaiian marine animals from the U.S. Fish and Wildlife Service website at <pacificislands.fws.gov>. (These marine animals include the Hawaiian monk seal, green sea turtle, and hawksbill sea turtle.) Students work in small groups to develop a short presentation on threatened and endangered marine species in Hawai'i. As a starting point, identify patterns and similarities among these threatened and endangered species: the similarities could be habitat, threats, distribution, conservation efforts, etc. Students can draw parts of their presentations on a map of the Hawaiian Islands, if they wish.

- Create a report that summarizes the key findings of the aquarium collection impact study in a popularly accessible, educational format. Students may include photos, graphs, and other graphics to augment the text of the report and make it visually appealing.

- Research whether there has been additional research done on the impacts of aquarium fish collecting on Hawaiian coral reef communities since Brian Tissot and Leon Hallacher completed their study in September 1999.

- Research what Fish Replenishment Areas and Regional Fishery Management Areas are under Hawai'i state law. The Department of Land and Natural Resources Division of Aquatic Resources is a good starting point for this research. Find out whether and where these protected areas exist on Maui. If none exist, research whether any have been proposed and why they have not been created.

- Research the traditional Hawaiian *kapu* system that was used to govern when and where fishing was allowed. Compare to today's approach to managing fisheries.

Resources for Further Reading and Research

Earth Trust, online curriculum about Hawai'i endangered species at <www.earthtrust.org/wlcurric/index.html>.

Coral Reef Network provides information about marine protected areas in Hawai'i at <www.coralreefnetwork.com>.

Hawai'i Department of Land and Natural Resources Division of Aquatic Resources, "Hawai'i Marine Life Conservation Districts" at <www.hawaii.gov/dlnr/dar/mlcd/index.html>.

Hawai'i Department of Land and Natural Resources Division of Aquatic Resources, *Current Line* newsletter at <www.hawaii.gov/dlnr/dar/current_line.htm>.

Activity #1

Weren't There More of Us? Game

● ● ● Class Period One *Weren't There More of Us?*

Materials & Setup

- "Actual Size at First Reproduction" poster (included with this curriculum)
- "Reef Animal Photos" (master, pp. 18-24)
- One set of "Discussion Question Cards" (master, p. 25)

Per student group (Play with groups of four to eight students OR with an entire class of up to forty students.)

- One set of 40 "Weren't There More of Us?" game cards (master, pp. 9-13)
- "Weren't There More of Us?" Species List (one per student if playing with a single large group—master, p. 14)
- "Weren't There More of Us?" Instruction Card for small or large groups (one per student if playing with a single large group—master, pp. 15-16)
- Hawai'i fishing regulations flyers (included with this curriculum and available from the Hawai'i Department of Land and Natural Resources, Division of Aquatic Resources)

Instructions

1) Tell students they are going to play a game in which the objective is to work cooperatively to correctly match Hawaiian reef animals with exactly five corresponding characteristics and fishing regulations.

2) Play the game with a whole class of up to forty students or divide students into groups of four to eight. Groups will work independently, so they do not need to be of equal size. Hand out the game cards, species list, and appropriate instruction card.

3) Review game instructions with students.

4) Before starting the game, show pictures of all eight reef animals to students, and provide the name of each animal. You may choose to make the photos available for student viewing during the game or make the game more challenging by having student examine the photos only once at the beginning of the game. Do not give further information about the animals and their characteristics.

5) During the activity, do not give students any clues about the identity of the animals.

6) Conduct the game according to the appropriate game instructions for your group size.

7) After the game, divide the class into four groups and give each group one Discussion Question card. Give groups several minutes to come up with a response to the question and then lead a class discussion about the game using these discussion questions.

Notes

- "Sustainable yield" generally refers to taking animals at a time and in a way that enables the populations to maintain themselves over time.
- Examples of actions that could supplement government regulations protecting reef animals include education, enforcement, and setting up marine protected areas where animals can grow to reproductive maturity because they are not fished or hunted there.

Journal Ideas

- In traditional Hawaiian culture, fishermen offered their first catch to the gods. Do you do this or know anyone who does? Why is this practice significant?
- Do you think that people respect government regulations such as fishing limits and seasons? Why or why not?
- Hawaiians traditionally viewed the ocean as their icebox, taking only what they needed at the time and coming back for more when necessary. Do you think this view still influences people who fish in Hawaiian waters? Why or why not? If it has changed, what might have contributed to these changes?
- Do you think it is important that future generations be able to enjoy and use the reef animals that we do today? Why or why not?
- What do you think are the most effective ways to protect reef animals?

Assessment Tools

- Participation in the game
- Group reasoning ability and correct responses during the game
- Participation in group and class discussion
- Journal entries

Teacher Background

Weren't There More of Us? — Answer Key

Lau'īpala, Yellow tang (*Zebrasoma flavescens*)

- I live on shallow reefs around islands from Hawai'i to southern Japan but am abundant only in Hawai'i.
- I graze on *limu* (seaweed) on the rocks near the shore in calm areas.
- I am bright yellow in color.
- I am a popular aquarium fish, and more of me are collected and exported than any other fish in Hawai'i.
- I am not protected by Hawai'i fishing regulations.

Moi, Six-fingered threadfin (*Polydactylus sexfilis*)

- I am silvery with a deeply forked tail and live near the ocean bottom.
- The lower part of my pectoral fin is very unusual in that it has six separate slender rays that I use to probe for food on the ocean bottom.
- I eat shrimps, crabs, worms and other invertebrates that I search for on the ocean bottom.
- Because I have become scarce from overfishing, I am being grown in aquaculture facilities and restocked into coastal waters.
- The season for me is closed June through August. I can be taken once I reach seven inches in length, but I do not reproduce until I'm 11 inches long. You can only take 15 of me.

'Opihi, Limpet (*Cellana* spp.)

- I am shaped like a volcano.
- I live on surf-swept lava rocks and hang on tightly with my muscular foot.
- I creep slowly and eat algae on the surface of the rocks.
- My populations are decreasing because I am collected off the rocks when I am too small and haven't had a chance to reproduce.
- I can be collected all year long, but my shell has to be at least 1 1/4 inches wide.

He'e mauli, Day octopus (*Octopus cyanea*)

- I am very hard to see because I can change my skin texture and color to blend in with the reef.
- When frightened, I can jet away or squirt out black ink.
- I mainly eat crabs, which I pounce on with the web between my arms spread wide.
- I am strongly attracted to certain cowries which were used in old times as lures to catch me.
- I can be taken all year long but need to weigh at least one pound.

Ula, Spiny lobster (two species of *Panulirus*)

- I have ten legs and a hard outer shell with forward-pointing spines.
- I hide in caves and crevices and come out at night to feed.
- The meat in my tail is a highly prized food.
- Since I am easy to catch in traps or tangle nets, I am vulnerable to overfishing.
- I cannot be taken from May through August. You can keep me only if my tail is at least 2 3/4 inches wide. You cannot fish for me with a spear or take me if I am a female with eggs.

Uhu, also *Pālukaluka,* Redlip parrotfish (*Scarus rubroviolaceus*)

- I am a sand maker. I bite off pieces of dead coral, then grind it to sand in hard plates in my throat.
- If I am a female, I can change sex and color and become a beautiful blue male.
- I am an herbivore. My teeth are fused together to form a beak for scraping algae off rock and dead coral.
- I have large scales covering my body, which help protect me.
- I can be speared or sold once I reach one pound. I am 14 inches long when I first spawn.

Ulua aukea, Giant trevally (*Caranx ignobilis*)

- I am silvery with a deeply forked tail and swim in midwater.
- I feed on fishes that I chase down.
- I can be five feet long and weigh 145 pounds.
- I can reproduce once I reach 21 inches in length, but you can legally catch me when I'm only seven inches long.
- I am usually caught by polefishing from the shore between dusk and dawn.

Kūmū, Whitesaddle goatfish (*Parupeneus porphyreus*)

- I am pinkish red in color and stay near the bottom of the reef.
- I have two barbels or sensory "feelers" on my chin that I wiggle while probing the bottom for crabs, worms, and snails.
- I can be taken at seven inches but don't reproduce until I'm 11 inches long. You can fish for me all year long, and there is no limit to the number that can be taken.
- I am found only in Hawai‘i. In the old days I was used as an offering to the gods when a red fish was needed.
- I am one of the largest of my type of fish, reaching 16 inches in length.

Weren't There More of Us? cards (cut on dashed lines)

I live on shallow reefs around islands from Hawaiʻi to southern Japan but am abundant only in Hawaiʻi.	**I am not protected by Hawaiʻi fishing regulations.**
I graze on *limu* (seaweed) on the rocks near the shore in calm areas.	**I am silvery with a deeply forked tail and live near the ocean bottom.**
I am bright yellow in color.	**The lower part of my pectoral fin is unusual in that it has six separate slender rays that I use to probe for food on the ocean bottom.**
I am a popular aquarium fish, and more of me are collected and exported than any other fish in Hawaiʻi.	**I eat shrimps, crabs, worms and other invertebrates that I search for on the ocean bottom.**

Weren't There More of Us? cards (cut on dashed lines)

Because I have become scarce from over-fishing, I am being grown in aquaculture facilities and restocked into coastal waters.	**I am shaped like a volcano.**
The season for me is closed June through August. I can be taken once I reach seven inches in length, but I do not reproduce until I'm 11 inches long. You can only take 15 of me.	**I live on surf-swept lava rocks and hang on tightly with my muscular foot.**
I creep slowly and eat algae on the surface of the rocks.	**My populations are decreasing because I am collected off the rocks when I am too small and haven't had a chance to reproduce.**
I can be collected all year long, but my shell has to be at least 1 1/4 inches wide.	**I am very hard to see because I can change my skin texture and color to blend in with the reef.**

Weren't There More of Us? cards (cut on dashed lines)

When frightened, I can jet away or squirt out black ink.	**I have ten legs and a hard outer shell with forward-pointing spines.**
I mainly eat crabs, which I pounce on with the web between my arms spread wide.	**I hide in caves and crevices and come out at night to feed.**
I am strongly attracted to certain cowries which were used in old times as lures to catch me.	**The meat in my tail is a highly prized food.**
I can be taken all year long but need to weigh at least one pound.	**Since I am easy to catch in traps or tangle nets, I am vulnerable to overfishing.**

Weren't There More of Us? cards (cut on dashed lines)

I cannot be taken from May through August. You can keep me only if my tail is at least 2 3/4 inches wide. You cannot fish for me with a spear or take me if I am a female with eggs.	**I am a sand maker. I bite off pieces of dead coral, then grind it to sand in hard plates in my throat.**
If I am a female, I can change sex and color and become a beautiful blue male.	**I am an herbivore. My teeth are fused together to form a beak for scraping algae off rock and dead coral.**
I have large scales covering my body, which help protect me.	**I can be speared or sold once I reach one pound. I am 14 inches long when I first spawn.**
I am silvery with a deeply forked tail and swim in midwater.	**I feed on fishes that I chase down.**

Weren't There More of Us? cards (cut on dashed lines)

I can be five feet long and weigh 145 pounds.

I can reproduce once I reach 21 inches in length, but you can legally catch me when I'm only seven inches long.

I am usually caught by polefishing from the shore between dusk and dawn.

I am pinkish red in color and stay near the bottom of the reef.

I have two barbels or sensory "feelers" on my chin that I wiggle while probing the bottom for crabs, worms, and snails.

I can be taken at seven inches but don't reproduce until I'm 11 inches long. You can fish for me all year long, and there is no limit to the number that can be taken.

I am found only in Hawai'i. In the old days I was used as an offering to the gods when a red fish was needed.

I am one of the largest of my type of fishes, reaching 16 inches in length.

Weren't There More of Us?

Species List

1. *Lau'īpala*, Yellow tang *(Zebrasoma flavescens)*

2. *Moi*, Six-fingered threadfin *(Polydactylus sexfilis)*

3. *'Opihi,* Limpet *(Cellana* spp.*)*

4. *He'e mauli*, Day octopus *(Octopus cyanea)*

5. *Ula*, Spiny lobster *(*two species of *Panulirus)*

6. *Uhu,* also *Pālukaluka,* Redlip parrotfish *(Scarus rubroviolaceus)*

7. *Ulua aukea*, Giant trevally *(Caranx ignobilis)*

8. *Kūmū*, Whitesaddle goatfish *(Parupeneus porphyreus)*

Weren't There More of Us?

Species List

1. *Lau'īpala*, Yellow tang *(Zebrasoma flavescens)*

2. *Moi*, Six-fingered threadfin *(Polydactylus sexfilis)*

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5. *Ula*, Spiny lobster *(*two species of *Panulirus)*

6. *Uhu,* also *Pālukaluka,* Redlip parrotfish *(Scarus rubroviolaceus)*

7. *Ulua aukea*, Giant trevally *(Caranx ignobilis)*

8. *Kūmū*, Whitesaddle goatfish *(Parupeneus porphyreus)*

Weren't There More of Us?

Game Instructions for Teams of Four to Eight Students

Object

Work cooperatively to match Hawaiian reef animals with exactly five corresponding characteristics and fishing regulations—the first team to make all the correct matches wins.

How to Play

1) Choose a dealer who gives one card to each player.

2) Play begins with the player to the right of the dealer and proceeds in a counter-clockwise direction.

3) The first player reads the information on his or her card aloud.

4) The entire group discusses which of the animals on the Species List the characteristic belongs to. The player with the card becomes that animal's "keeper." Consult the fishing regulations flyer and "Size at First Reproduction" poster for help when you need it.

5) The second player reads the information on her or his card.

6) After group discussion, the group may decide that the second animal is the same as the first animal. If so, the card is given to the first "keeper." If the second animal is different than the first, the second player keeps the card and becomes the "keeper" of the second animal.

7) Continue until all the first round cards have been read and assigned to a keeper.

8) Continue dealing rounds of cards and assigning them to animals, as before.

9) After the second round, there may be some players without animals to "keep" and some with more than one animal. When that happens, a player without an animal to keep should "adopt" one from a player who is keeping more than one animal, so each player has an animal to keep. If there are fewer than eight players, some will have more than one animal.

10) When all the cards have been assigned, keepers should have exactly five fact cards for each animal. If some animals have more than five cards, you must determine which cards have been incorrectly assigned. Some features may overlap slightly, so your team will need to discuss the possibilities and look for clues to the correct match.

11) When you think you have the correct matches, ask your instructor to check your team's work.

Weren't There More of Us?

Game Instructions for Groups Up to Forty Students

Object

Work cooperatively to match Hawaiian reef animals with exactly five corresponding characteristics and fishing regulations

How to Play

1) Pass out all the cards. Some players may have more than one.

2) Players read the information on their card(s) and try to determine the identity of the animals.

3) When players think they know what their animal(s) is, they call out the name. For example, a person with the card that says, "I have a lush fur coat," calls out, "Monk seal!"

4) Other players listen to the names being called out and try to fit the information on their cards into one of the animal groups. They give their cards to the first person who called out the name of a particular animal. That person is designated the "keeper," and the other students join him or her to find the other correct matches for that animal.

5) When all the cards have been added to a set, keepers should have exactly five fact cards for each animal. If some animals have more than five cards, players must get together to determine which cards have been incorrectly assigned. Some features overlap slightly, so you will need to discuss the possibilities and look for clues to the correct match.

6) Consult the fishing regulations flyer and "Size at First Reproduction" poster for help as needed.

7) At the end of the game, ask your instructor to check the sets to determine if they are correct.

Lau'īpala, Yellow tang (*Zebrasoma flavescens*)

Photo: John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

Moi, Six-fingered threadfin (*Polydactylus sexfilis*)

Photo: John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

'Opihi, Limpet (*Cellana* spp.)

Cellana exarata *pictured (Photo: Ann Fielding)*

He'e mauli, Day octopus (*Octopus cyanea*)

Photo: David R. Schrichte in John P. Hoover,
Hawai'i's Sea Creatures, *Mutual Publishing*

Ula, Spiny lobster (two species of *Panulirus*)

Panulirus marginatus *pictured*
(Photo: John P. Hoover, Hawai'i's Sea Creatures, *Mutual Publishing)*

Uhu, also *Pālukaluka,* Redlip parrotfish (*Scarus rubroviolaceus)*

Photo: Bruce Carlson

Ulua aukea, Giant trevally (*Caranx ignobilis*)

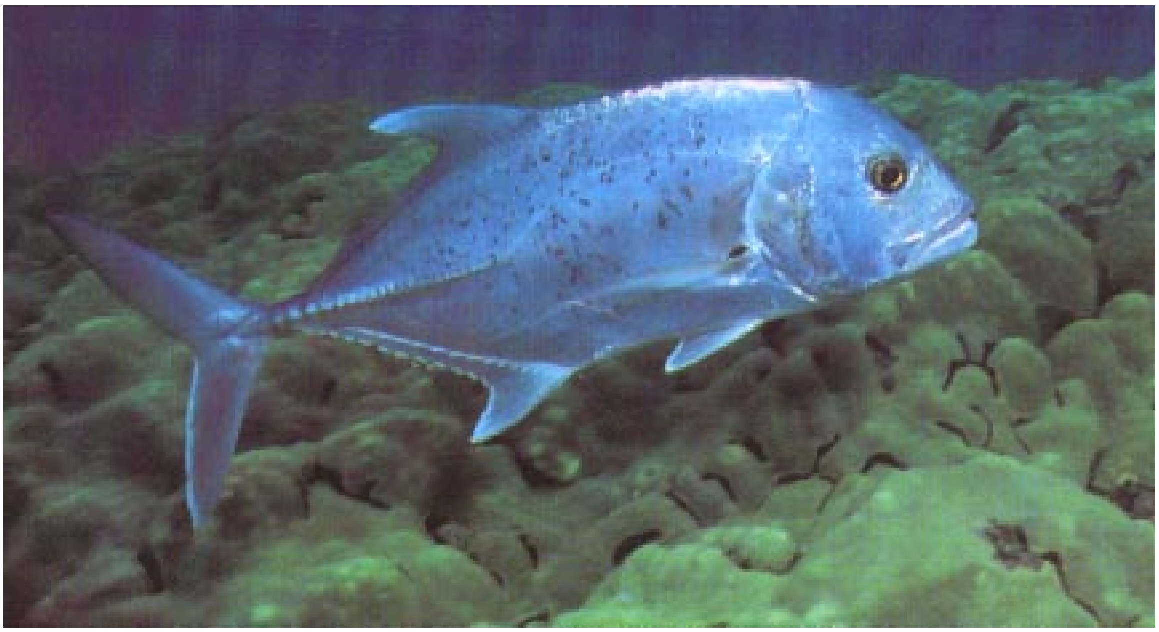

Photo: David R. Schrichte in John P. Hoover,
Hawaii's Fishes, *Mutual Publishing*

Kūmū, Whitesaddle goatfish
(*Parupeneus porphyreus*)

Photo: John P. Hoover, Hawaii's Fishes, *Mutual Publishing*

Discussion Question Cards

Cut apart on dashed lines

Most of the reef animals in the game are protected by regulations such as closed seasons, size limits, and limits on numbers of animals that can be taken. But, as you learned, the size limits on some species allow people to take animals that have not been able to reproduce yet. Does this seem smart to you? Why or why not?

What do you think the best way is to protect populations of reef animals? Explain your answer.

What do you think the term "sustainable yield" means when it comes to catching or collecting reef animals?

The government regulates the taking of reef animals that have been determined to be at risk for overfishing/harvesting. Do you think fishing/hunting regulations are effective tools for protecting reef animals? Do you think they can work by themselves?

Activity #2

Impacts of Aquarium Fish Collecting on Coral Reefs

● ● ● In Advance *Student Assignment*

- As homework, assign the Student Pages "Impacts of Aquarium Fish Collectors on Coral Reef Fishes in Kona, Hawai'i" (pp. 34-41) and "Questions About the Reading" (pp. 42-45).

● ● ● Class Period One *Discussing Study Designs*

Materials & Setup

For each student

- Student Page "Impacts of Aquarium Fish Collectors on Coral Reef Fishes in Kona, Hawai'i" (pp. 34-41)
- Student Page "Questions About the Reading" (pp. 42-45)

Instructions

1) Beginning with student questions and responses to the homework assignment, hold a class discussion about the study, its design, conclusions, and implications for managing coral reef fisheries.

2) For advanced classes, move from the general discussion to a more detailed discussion of experimental design. For guidance and background, use "Impacts of Aquarium Collectors on Coral Reef Fishes in Kona, Hawai'i" (complete original report in appendix) and "Notes for Class Discussion on 'Impacts of Aquarium Collectors on Coral Reef Fishes'" (pp. 28-29).
   The class discussion should get into the details of experimental design at an appropriate depth for the level of students. Students should be prepared for this discussion based on their reading and answering the homework questions.

3) Wrap up the discussion by focusing on the final homework question, how students would go about learning whether aquarium collecting is a current problem on Maui and what they would do to prevent it from becoming a problem in the future.

Journal Ideas

- If you were in charge of regulating aquarium fish collecting, what would you do based on reading the Tissot and Hallacher study?
- Do you think that people should be allowed to collect native Hawaiian fish for the aquarium trade? Why or why not?

Assessment Tools

- Student Page "Questions About the Reading" (teacher version, pp. 30-33)
- Participation in class discussion
- Journal entries

Teacher Background

Notes for Class Discussion on "Impacts of Aquarium Collectors on Coral Reef Fishes"

To make the main points of this paper easier for students to grasp, several parts of the study and discussion were left out of the simplified student version of the paper. Depending upon the level of student and the nature of the course you are teaching, you will want to go into details of the study that will help students understand experimental design.

Below are the main elements of the paper, along with page references to the full version of the paper (see appendix). First, make sure that students understand the results of the study as presented in the student version. Then, with the time remaining, go into the elements of experimental design, emphasizing the first three sections of the paper.

1) Introduction/statement of the problem (pp. 4-5)
   The context for this study is the growing global and Hawaiʻi-based trade in marine aquarium fishes collected from the wild. The authors identified a lack of conclusive studies documenting the magnitude of impacts on natural populations.

2) Scope/purpose of the study (p. 4)
   This study had two main purposes. Only the first is covered in the student version of the paper:
   a) Obtain quantitative estimates of the impact of aquarium collectors on reef fishes;
   b) Evaluate evidence for destructive harvesting methods and changes in the reef community associated with reductions in herbivory (predation on plants).

3) Methods (pp. 5-7)
   a) The authors explain their experimental design (a paired control-impact design) and its major assumptions. The student version of the paper deals very little with the assumptions of the design and how they were tested/addressed. The main assumptions and how they were tested and addressed in the study and report are:

Assumption	How addressed, tested
Prior to the onset of aquarium harvesting, there was no difference in abundance of aquarium fishes between the control and impact sites. (The study was begun after the impacts had begun.)	• Paired control and impact sites were geographically close together (p. 10). • The survey was conducted on corals, macroalgae, and the general substratum of each transect. Analysis showed remarkable similarity between the paired control-impact sites (pp. 8, 10). • The survey included ecologically similar species not targeted by aquarium collectors. A prediction of this assumption is that non-collected species should not differ between control and impact sites. This prediction was supported by study data (pp. 6, 8-10).

Assumption	How addressed, tested
All differences between the control and impact sites are due to aquarium fish collecting and not other factors, such as fishing.	• Impact sites were largely inaccessible from shore, minimizing shore-based recreational fishing (p. 10). • There was no significant control-impact variation in abundance of a nontarget species (not collected for aquariums) subject to commercial and recreational fishing (p. 10). • Introduced piscivorous (fish-eating) fishes that may cause significant mortality among aquarium species were rare at the study sites (pp. 10-11).

b) The authors also describe their research sites, methods, personnel, and timing of the surveys, as well as steps they took to minimize bias (pp. 6-7). Much of this detail has been left out of the student version of the paper.

c) Methods of analysis are described (p. 7). Only the basic calculation of percent change in abundance is described in the student version of the paper. The analysis for statistical significance is not described in the student version, nor were the factors included (impact, location, and impact-location).

4) Results (pp. 6-9)
In the student version of the paper, this section is condensed and combined with the discussion section, primarily because so many of the results had to do with analyses not covered in the student paper.

5) Discussion (pp. 9-13)
In this paper, the discussion of results has four sections:
-Evaluation of assumptions (see table above)
-Magnitude of impacts (eliminated from the student version)
-Indirect effects (eliminated from the student version)
-Implications for fishery management

6) Acknowledgments (p. 13)

7) References
References in the student version have been modified based on editing the original.

8) Tables and figures
Only some of the tables from the original paper are in the student version.

Teacher Version

Questions About the Reading

Answer the following questions. Attach additional sheets if necessary.

1) What was the purpose of the study?

   To examine the effects of aquarium collecting on reef fish populations in Hawai'i

2) Why did the researchers choose to survey both fish species that are commonly collected for the aquarium trade and those that are not?

   Each nontargeted fish species was chosen because its habitat and food type are similar to one or more targeted species. These nontarget species provided a base of comparison that helped researchers determine whether the changes in population were related to aquarium collecting.

3) Explain what the "impact" sites were and what the "control" sites were and why they are important in this study.

   The impact sites were areas with high levels of aquarium collecting. The control sites were adjacent to impact sites, in areas where aquarium collecting is prohibited. Researchers could estimate the magnitude of impact by comparing population density and changes in population density at sites where aquarium collecting occurs and where it does not.

4) The researchers were interested in determining how much difference there was between fish abundance at the control and impact sites. They determined the mean density of fish at each of the sites. Then they calculated a percent change in fish abundance for each species, and for each species at each of the two study sites.

A negative percent change indicates fewer fish at the impact relative to the control site, while a positive value indicates the opposite pattern.

Species	Mean overall percent change
Aquarium fishes	
Achilles tang (*Acanthurus achilles)*	-57.1
Potter's angelfish (*Centropyge potteri)*	-46.1
Multi-band butterflyfish (*Chaetodon multicinctus)*	-38.2
Ornate butterflyfish (*Chaetodon ornatissimus*)	-39.5
Four-spot butterflyfish (*Chaetodon quadrimaculatus)*	-41.6
Goldring surgeonfish (*Ctenochaetus strigosus*)	-14.7
Longnose butterflyfish (*Forcipiger* spp.)	-54.2
Orangespine unicornfish (*Naso lituratus*)	31.2
Moorish idol (*Zanclus cornutus*)	-46.5
Yellow tang (*Zebrasoma flavescens*)	-47.3
Non-Aquarium Species	
Brown surgeonfish (*Acanthurus nigrofuscus*)	27.3
Blueline surgeonfish *(Acanthurus nigroris)*	67.2
Convict surgeonfish or tang *(Acanthurus triostegus)*	-4.3
Oval butterflyfish *(Chaetodon lunulatus)*	-70.0
Arc-eye hawkfish *(Paracirrhites arcatus)*	-36.4
Blackside hawkfish *(Paracirrhites forsteri)*	58.4
Blue-eye damsel *(Plectroglyphidodon johnstonianus)*	-31.3
Pacific gregory *(Stegastes fasciolatus)*	326.0
Saddle wrasse *(Thalassoma duperrey)*	17.4

4a) Which three species show the greatest difference between the number of individuals at control sites and impact sites? For each species, identify whether this difference indicates that there are fewer individuals at the control sites or the impact sites.

Pacific gregory *(Stegastes fasciolatus)* — fewer at control sites

Oval butterflyfish *(Chaetodon lunulatus)* — fewer at impact sites

Blueline surgeonfish *(Acanthurus nigroris)* — fewer at control sites

4b) Which four species show the greatest negative mean percent change—indicating fewer individuals at the impact sites relative to the control sites? Discuss the possible significance of these results based on whether these species are collected for the aquarium trade or not.

Oval butterflyfish (*Chaetodon lunulatus*)
Achilles tang (*Acanthurus achilles*)
Longnose butterflyfish (*Forcipiger spp.*)
Yellow tang (*Zebrasoma flavescens*)

Three of the four species are targeted by aquarium collectors. This probably indicates that aquarium collection, which occurs at the impact sites and not the control sites, decreases fish populations.

5) What patterns do you notice when you compare the aquarium species with the non-aquarium species, looking at whether the percent change is negative or positive? What do these patterns suggest about the impact of aquarium collecting?

All but one of the aquarium species show a negative percent change, while the results are mixed among non-aquarium species (three negative and four positive). This result suggests that aquarium collecting decreases populations of target species and that other factors might also have come into play (because of the mixed results among the non-aquarium species).

6) The experimental design that the researchers selected for this study makes two major assumptions:
   a) The study began after aquarium fish collecting had already started in the impact areas. Therefore, the design assumes that the natural abundance of aquarium fishes at the control and impact sites were similar prior to the onset of aquarium collection.
   b) The design assumes that all differences between the paired control and impact sites were due to aquarium fish collecting and not other factors, such as fishing.

Choose one of these assumptions and think of a way that the researchers could — or did — build into the study a way to test whether the assumption seems valid.

There are many correct responses to this question, which should be evaluated based on student reasoning, as well as references back to the study:

a) One way the researchers controlled for the first assumption was to select control and impact sites that are close together, to lessen the likelihood of spatial variation. They also used a combination of nontarget species that were ecologically similar to target species, and other species that were indicators of particular habitats, as indicators of the ecological similarity of the control and impact sites.

Other ways of assessing the correctness of this assumption include comparing control and impact sites for factors such as species diversity and richness, and comparing the habitats by looking at coral and algae abundance and diversity, and non-living substratum composition.

b) One way to control for the second assumption is to select sites that are largely inaccessible from shore, to minimize the impact of shore-based recreational fishing. (The authors did this in the aquarium collecting study, but that may not be clear from the student background reading.)

Other ways of testing the assumption include looking at density variation in target and nontarget species that are subject to commercial and recreational fishing. If the density of nontarget species that are fished for does not vary between control and impact sites, this suggests that fishing impacts are not significant.

Another factor that could differentially affect reef fish populations could be the presence of predator fishes. Including predator fishes in the surveys would help determine whether this factor does influence reef fish populations.

7) Some people say that aquarium collecting is not a problem on Maui, while others believe that it is a problem in some areas or could quickly become one. Write one paragraph about what you would do to find out whether aquarium collecting is a threat to Maui reef animals. Write another paragraph about what you think should be done, if anything, to protect Maui reef fish populations from the impacts of collecting.

Well-reasoned responses are acceptable.

Impacts of Aquarium Collectors on Coral Reef Fishes in Kona, Hawai'i

This paper is condensed with authors' permission from a September 1999 report of the same name prepared for the State of Hawai'i Division of Aquatic Resources by Brian N. Tissot, Ph.D. (Washington State University — Vancouver) and Leon E. Hallacher, Ph.D. (University of Hawai'i – Hilo). This distillation of their paper focuses on the first goal of their study: to obtain "quantitative" or number-based estimates of the impact of aquarium collectors on reef fishes. It does not cover methods, data, or conclusions associated with the second goal of the study: to evaluate evidence for destructive fish harvesting methods and changes in the reef community associated with reductions in herbivory.

Introduction

Each year, some 350 million ornamental aquarium fish worth $963 million are sold around the world (Young, 1997). Although marine fishes account for only ten to 20 percent of the total, the harvest level for marine species grew rapidly in the1980s (Andrews, 1990). Over 99 percent of marine fishes sold in the aquarium trade are taken from the wild, unlike their freshwater counterparts, most of which are cultivated (Young, 1997). Almost all marine ornamentals are of tropical origin and many are harvested from coral reefs. Because aquarium fish collectors focus heavily on a few species and often capture large quantities of individuals of high value, the potential for overfishing is high (Wood, 1985).

Many studies have discussed the potential effects of the aquarium trade on marine fishes in Australia (Whitehead et al., 1986), Hawai'i (Taylor, 1978; Walsh, 1978; Randall, 1987), Indonesia (Wood, 1985), the Philippines (Albaladejo and Corpuz, 1981), Puerto Rico (Sadovy, 1992), and Sri Lanka (Edwards and Shepherd, 1992). But there are no conclusive studies documenting the magnitude of impacts on fish populations, despite repeated calls for such studies to help sustain the aquarium trade industry over the long term (Walsh, 1978; Wood, 1985; Young, 1997).

Most of the marine ornamentals originating from the U.S. are taken from Hawai'i waters. Hawai'i is known for its high-quality fishes and rare endemic fishes of high value (Wood, 1985). As early as the 1970s, concerns over the effects of aquarium collecting on reef fish populations in Hawai'i were being raised. (Taylor, 1978; Walsh, 1978). Aquarium fish collectors and recreational dive tour operators came into conflict over apparent declines in nearshore reef fishes (Taylor, 1978). This conflict continues up to the present (Grigg, 1997; Young, 1997; Clark and Gulko, 1999). Early concerns prompted the Hawai'i Division of Fish and Game [now the Division of Aquatic Resources] to require monthly collection reports of all permit holders starting in 1973 (Katekaru, 1978). These reports have been the primary basis for managing the aquarium industry in Hawai'i since then (Miyasaka, 1994, 1997).

Data from collection reports suggest that the size and value of the Hawai'i aquarium fish industry is growing. In 1973, 90,000 fishes with a total value of $50,000 were reported (Katekaru, 1978). In 1995, the annual harvest had risen to 422,823 fishes with a total value of $844,843 (Miyasaka, 1997).

Although a total of 103 fish species were collected statewide in 1995 (Division of Aquatic Resources [DAR], unpublished data), over 90 percent of the harvest is focused on 11 species. The yellow tang (*Zebrasoma flavescens*) accounted for 52 percent of the total harvest in 1995 (DAR, unpublished data; Miyasaka, 1997). Given the increasing rate of harvest focused on a small number of species, the potential for "overexploitation" is high, meaning the fishes are taken at such a rate that they cannot maintain their populations over the long term.

Materials and Methods

We used a "paired control-impact design" to estimate the impact of aquarium collectors on the "abundance" or relative numbers of reef fish in an area. The magnitude of the impact was estimated by comparing the difference between fish abundance at "impact" sites, where aquarium fish collecting was known to occur, relative to nearby "control" sites where collecting was prohibited.

We established four study sites that served as two control-impact pairs for the study (Figure 1). Impact sites were selected in areas where high levels of aquarium fish collecting was occurring (personal communications). Control sites were located in areas adjacent to impact sites, where aquarium fish collecting was prohibited.

The first pair of study sites were located at Honokōhau and Papawai on the island of Hawai'i. Papawai is a Fishery Management Area (FMA) where the collecting of aquarium fishes is prohibited (DLNR, 1996). It served as a control site. Honokōhau was frequented by aquarium collectors and served as an impact site. These paired sites will hereafter be referred to as the "Honokōhau" study area. The second pair of study sites were located at Red Hill North and South. Red Hill South is a FMA where the collecting of aquarium fishes is prohibited (DLNR, 1996), and which served as a control site. Red Hill North was frequented by aquarium collectors and served as an impact site. These paired sites will hereafter be referred to as the "Red Hill" study area.

At each study site four permanent 50-meter "transects" or lines were established at ten to 15 meter depths by installing stainless steel eyebolts at the beginning and end points of each. The abundances of fishes was estimated using a visual strip-transect search method (Sale and Douglas, 1981). In this method, a pair of divers swam side-by-side down either side of the transect line and count all fish seen within a corridor three meters wide and extending to the surface.

Surveys began at Honokōhau in March, and at Red Hill in September, of 1997 and ended at both sites in December 1998. All sites were sampled at

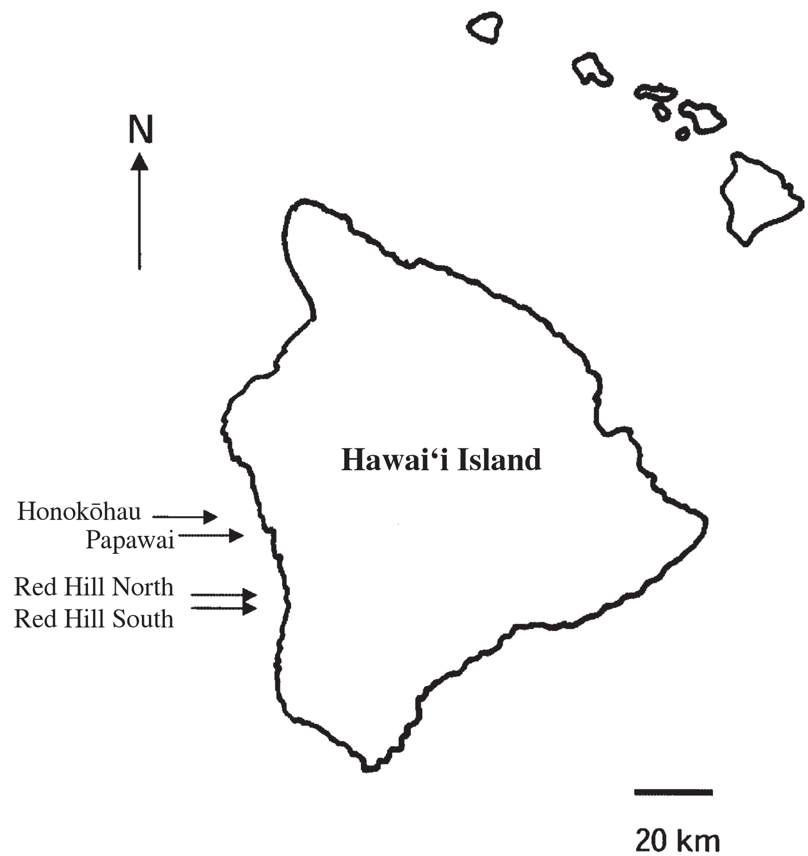

Figure 1. Map of study sites located on the island of Hawai'i

intervals of two to five months for a total of eight surveys at Honokōhau and five at Red Hill.

During each survey we estimated the abundance of 21 fish species (Table 1). Eleven aquarium fish species were selected based on reported high levels of collection. In addition, we also surveyed ten fish species not targeted by aquarium collectors. These species were selected to serve as indicators of specific habitats and food types and provide data to support the study's assumptions.

The divers used in this study were undergraduates who had completed a rigorous coral reef-monitoring course and were trained in species identification and survey techniques (Russell, 1997; Hallacher and Tissot, 1999). In order to minimize observer bias, the same diver-pairs were used at each control-impact study site during each survey. Divers did, however, vary among surveys. To minimize variation, all surveys were conducted in the middle of the day (generally from 9:00 a.m. to 3:00 p.m.) and both control and impact sites were surveyed either on the same day or on consecutive days.

Percent change in fish abundance was calculated as the difference between both control sites and both impact sites using the formula:

$$\text{Percent change} = [(D_{impact} - D_{control})/D_{control}] \times 100$$

Where D = density expressed as number of individuals per 100 square meters. Thus, a negative percent change indicates fewer fish at the impact relative to the control sites, while a positive value indicates the opposite pattern.

Results and Discussion

Of the 21 species surveyed, two species (Racoon butterflyfish, *Chaetodon lunula,* and Teardrop butterflyfish, *C. unimaculatus*) were too rare for analysis with one individual of each species observed during the entire study. These species were excluded from any further analysis.

Overall, there were numerous "significant" differences (which are unlikely to occur based on chance alone) in the abundance of aquarium fishes between control and impact sites but few differences in the abundance of non-aquarium species (Table 2).

The results of this study indicate that eight of the ten fishes targeted by aquarium collectors were significantly reduced in abundance in areas subjected to harvesting, relative to managed areas where collecting was prohibited. The magnitude of these declines ranged from 57 percent in Achilles tang *(Acanthurus achilles)* to 38 percent in Multi-band butterflyfish *(Chaetodon multicinctus)*. In contrast, only one of the nine "nontarget" species not typically collected for aquariums varied significantly between these areas, suggesting that aquarium collectors are having significant impacts on the abundance of targeted fishes in near-shore areas on the Kona coast of Hawai'i.

Evaluation of Assumptions

Part of the design of this study was to use a combination of nontargeted species that were ecologically similar to target species (those that are collected for the aquarium trade). This is one way to infer whether observed differences are due to the impact of aquarium collectors or due to other differences between the control and impact sites.

Overall, aquarium fishes exhibited significant differences between control and impact sites, while nontarget species did not. Table 3 details some of these comparisons.

The one exception to this pattern was the Arc-eye hawkfish (*Paracirrhites arcatus*), the only nontarget species that was significantly less abundant in impact relative to control areas. This species lives in close association with corals, primarily *Pocilliopora meandrina*, which although rare at all study sites, was less abundant at impact relative to control sites.

Implications for Fishery Management

This study indicates that aquarium collectors are having significant impacts on eight of the ten

(Continued on p. 40)

Table 1. List of fishes monitored during the study

Information on diet and trophic level is based on Randall (1985, 1996).

SPECIES	TROPHIC LEVEL	DIET
Aquarium fishes		
Achilles tang (*Acanthurus achilles*)	Herbivore	Filamentous algae
Potter's angelfish (*Centropyge potteri)**	Herbivore	Filamentous algae and detritus
Racoon butterflyfish (*Chaetodon lunula*)°	Carnivore	Small invertebrates
Multi-band butterflyfish (*Chaetodon multicinctus)**	Corallivore	Coral polyps
Ornate butterflyfish (*Chaetodon ornatissimus)*	Corallivore	Coral polyps
Four-spot butterflyfish (*Chaetodon quadrimaculatus*)	Corallivore	Coral polyps
Goldring surgeonfish (*Ctenochaetus strigosus*)	Detritivore	Detritus
Longnose butterflyfish (*Forcipiger* spp.)•	Carnivore	Small invertebrates
Orangespine unicornfish (*Naso lituratus*)	Herbivore	Macroalgae
Moorish idol (*Zanclus cornutus*)	Omnivore	Sponges and algae
Yellow tang (*Zebrasoma flavescens*)	Herbivore	Filamentous algae
Nonaquarium fishes		
Brown surgeonfish (*Acanthurus nigrofuscus*)	Herbivore	Filamentous algae
Blueline surgeonfish (*Acanthurus nigroris)* *	Herbivore	Filamentous algae
Convict tang (*Acanthurus triostegus*)	Herbivore	Filamentous algae
Teardrop butterflyfish (*Chaetodon unimaculatus*)°	Corallivore	Coral polyps
Oval butterflyfish (*Chaetodon lunulatus*)	Corallivore	Coral polyps
Arc-eye hawkfish (*Paracirrhites arcatus*)	Carnivore	Invertebrates and fishes
Blackside hawkfish (*Paracirrhites forsteri*)	Carnivore	Invertebrates and fishes
Blue-eye damsel (*Plectroglyphidodon johnstonianus*)	Corallivore	Coral polyps
Pacific gregory (*Stegastes fasciolatus*)	Herbivore	Filamentous algae and detritus
Saddle wrasse (*Thalassoma duperrey*)*	Carnivore	Invertebrates

* endemic to Hawai'i ° too rare to be included in the analysis
• two species of longnose butterflyfish were included in this category

Table 2. Mean density of aquarium and nonaquarium fishes at control and impact study sites pooled for the entire study

	Density (no. / 100 m^2)			
	Honokōhau		Red Hill	
	Impact	Control	Impact	Control
Aquarium fishes				
Acanthurus achilles	0.23	0.69	0.40	0.92
Centropyge potteri	1.48	2.50	0.25	0.85
Chaetodon multicinctus	2.98	4.95	3.43	5.72
Chaetodon ornatissimus	0.25	0.59	0.57	1.37
Chaetodon quadrimaculatus	0.01	0.15	0.17	0.38
Ctenochaetus strigosus	24.10	35.60	32.10	28.70
Forcipiger spp.	1.27	3.24	0.75	1.33
Naso lituratus	1.58	1.25	0.92	1.72
Zanclus cornutus	0.34	0.89	0.28	0.65
Zebrasoma flavescens	9.72	19.80	14.30	24.40
Overall Density	42.00	69.7	53.20	66.00
Nonaquarium fishes				
Acanthurus nigrofuscus	12.10	11.30	23.90	17.60
Acanthurus nigroris	1.24	2.60	3.42	1.68
Acanthurus triostegus	0.16	0.32	0.17	0.13
Chaetodon lunulatus	0.26	0.11	0.00	0.00
Paracirrhites arcatus	1.28	1.56	0.87	3.68
Paracirrhites forsteri	0.42	0.17	0.15	0.60
Plectroglyphidodon johnstonianus	1.82	2.11	0.97	1.93
Stegastes fasciolatus	1.29	0.73	0.15	0.10
Thalassoma duperrey	3.91	3.22	3.30	3.65
Overall Density	22.50	22.20	32.90	29.40

Table 3: Comparisons in change in abundance among similar target and nontarget species

Species	Similar characteristics	Change in abundance
Nontarget Brown surgeonfish (*Acanthurus nigrofuscus*)	Generalized herbivores that feed on filamentous algae, occupy the same depth ranges and habitats, and exhibit similar patterns of spawning and larval recruitment (Randall, 1985; Walsh, 1987; Lobel, 1989)	No significant variation between impact and control sites
Target Yellow tang (*Zebrasoma flavescens*)		Forty-seven percent less abundant at impact sites than at control sites
Nontarget Oval butterflyfish (*Chaetodon lunulatus*) Blue-eye damsel (*Plectroglyphidodon johnstonianus*)	Feed on coral or live in close association with coral	No significant variation between impact and control sites
Target Multi-band butterflyfish (*Chaetodon multicinctus*) Ornate butterflyfish (*C. ornatissimus*) Four-spot butterflyfish (*C. quadrimaculatus*)		Significantly lower abundances at impact sites
Nontarget Blueline surgeonfish (*Acanthurus nigroris*) Convict surgeonfish (*A. triostegus*) Blackside hawkfish (*Paracirrhites forsteri*) Pacific gregory (*Stegastes fasciolatus*) Saddle wrasse (*Thalasoma duperrey*)	Generalized diets and distributions across the reef	No significant variation between impact and control sites
Target Achilles tang (*Acanthurus achilles*) Potter's angelfish (*Centropyge potteri*) Moorish idol (*Zanclus cornutus*)		Significantly lower abundances at impact sites

species examined. However, more specific information about location, catch and effort is essential to verify the results of this study. The current system of catch reporting in Hawai'i is limited to monthly collecting reports, with the 235-kilometer (146-mile) coastline of west Hawai'i divided into three large sections (Miyasaka, 1997). These reports are not compared to actual catches, so there is no quality assurance that the reports are accurate. Analysis of the current catch reports indicates that significant numbers of reports are not filed (DAR, personal communication). Routine monitoring of the collector's catch report should be instituted to provide some level of quality assurance about the reported catch data.

The magnitude and extent of the impacts documented in this study clearly point to an increased need for management of these species in Hawai'i. Responding to continued strong public outcry over the aquarium collecting issue, the Hawai'i state legislature passed a bill in 1998 which focused on improving management of reef resources. The law established the West Hawai'i Regional Fishery Management Area. It also set aside a minimum of 30 percent of the west Hawai'i coastline as Fish Replenishment Areas (FRAs), protected areas where aquarium fish collecting is prohibited. Based largely on input from the West Hawai'i Fishery Council, a community-based group of individuals, a network of nine FRAs has been proposed as a plan to manage the aquarium industry. Our current efforts are focused on monitoring these areas in order to evaluate the effectiveness of the proposed reserve network as a fishery management tool. Through monitoring of changes in abundance in the reserves relative to existing protected and impact areas (including the Honokōhau and Red Hill study sites), we will be able to test predictions derived from the results of this study.

Acknowledgments

We thank Brent Carmen, John Kahiapo and John Coney for logistical support during this project. The actual fish counts were conducted by Rob Ames, Anne Creason, Brent Larsen, Bryan Doo, John Holland, Greg Polloi, Jill Sommer, Monica Gregorita, Michelle Pico, and Rachelle Spears. Jonathan Hultquist analyzed all of the photoquadrat images. Robert Nishimoto, Peter Hendricks, Sara Peck, and David Tarnas assisted in planning and design. The research was supported from a grant from the Hawai'i Division of Aquatic Resources.

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Questions About the Reading

Answer the following questions. Attach additional sheets if necessary.

1) What was the purpose of the study?

2) Why did the researchers choose to survey both fish species that are commonly collected for the aquarium trade and those that are not?

3) Explain what the "impact" sites were and what the "control" sites were and why they are important in this study, and to research in general.

4) The researchers wanted to determine how much difference there was between fish abundance at the control and impact sites. They determined the mean density of fish at each of the sites. Then they calculated a percent change in abundance for each species.

A negative percent change indicates fewer fish at the impact relative to the control site, while a positive value indicates the opposite pattern.

Species	Mean percent change for both study sites
Aquarium fishes	
Achilles tang (*Acanthurus achilles*)	-57.1
Potter's angelfish (*Centropyge potteri*)	-46.1
Multi-band butterflyfish (*Chaetodon multicinctus*)	-38.2
Ornate butterflyfish (*Chaetodon ornatissimus*)	39.5
Four-spot butterflyfish (*Chaetodon quadrimaculatus*)	-41.6
Goldring surgeonfish (*Ctenochaetus strigosus*)	14.7
Longnose butterflyfish (*Forcipiger* spp.)	-54.2
Orangestripe unicornfish (*Naso lituratus*)	31.2
Moorish idol (*Zanclus cornutus*)	-46.5
Yellow tang (*Zebrasoma flavescens*)	-47.3
Nonaquarium Species	
Brown surgeonfish (*Acanthurus nigrofuscus*)	27.3
Blueline surgeonfish (*Acanthurus nigroris*)	67.2
Convict tang (*Acanthurus triostegus*)	-4.3
Oval butterflyfish (*Chaetodon lunulatus*)	-70.0
Arc-eye hawkfish (*Paracirrhites arcatus*)	-36.4
Blackside hawkfish (*Paracirrhites forsteri*)	58.4
Blue-eye damsel (*Plectroglyphidodon johnstonianus*)	-31.3
Pacific gregory (*Stegastes fasciolatus*)	326.0
Saddle wrasse (*Thalassoma duperrey*)	17.4

4a) Which three species show the greatest difference between the number of individuals at control sites and impact sites? For each species, identify whether this difference indicates that there are fewer individuals at the control sites or the impact sites.

4b) Which four species show the greatest negative mean percent change—indicating fewer individuals at the impact sites relative to the control sites? Discuss the possible significance of these results based on whether these species are collected for the aquarium trade or not.

5) What patterns do you notice when you compare the aquarium species with the non-aquarium species, looking at whether the percent change is negative or positive? What do these patterns suggest about the impact of aquarium fish collecting?

6) The experimental design that the researchers selected for this study makes two major assumptions:
   a) The study began after aquarium fish collecting had already started in the impact areas. Therefore, the design assumes that the natural abundance of aquarium fishes at the control and impact sites were similar prior to the onset of aquarium collection.
   b) The design assumes that all differences between the paired control and impact sites were due to aquarium fish collecting and not other factors, such as sport fishing or pollution.

   Choose one of these assumptions and think of a way that the researchers could — or did — build into the study a way to test whether the assumption seems valid.

7) Some people say that aquarium collecting is not a problem on Maui, while others believe that it is a problem in some areas or could quickly become one. Write one paragraph about what you would do to find out whether aquarium collecting is a threat to Maui reef animals. Write another paragraph about what you think should be done, if anything, to protect Maui reef fish populations from the impacts of collecting. (If you played the "Weren't There More of Us?" game, how did what you learned from that game influence your response to these questions?)

Activity #3

Design a Monitoring Study

● ● ● In Advance *Student Assignment*

- As homework, assign the Student Page “Design Your Own Monitoring Study” (pp. 48-52). You may want to give students several days to complete this assignment, allowing students ample time to complete their study designs. If you want students to research and footnote any parts of their design proposals (such as the project background), let them know this in advance.

● ● ● Class Period One *Discussing Study Designs*

Materials & Setup

For each student

- Student Page “Design Your Own Monitoring Study” (pp. 48-52)

Instructions

1) Divide the class into four or five small groups. Have students describe their study designs to other students in their group. Each group should select the best study design from the ones presented.

2) Bring the whole class back together and have the students whose study designs were selected by the groups present them to the whole class. Lead a discussion about the similarities and differences in the designs and how this kind of monitoring information could affect how natural areas are managed.

3) Have the class vote on the best study design of those selected by the groups. The class will present that study design to the Department of Land and Natural Resources (DLNR) on Maui. Select a small committee of students to write a cover letter describing what the class has learned during this unit and offering the study design as a suggested way for DLNR to monitor ‘Āhihi-Kīna‘u Natural Area Reserve.

Journal Ideas

- Describe one point of similarity and one point of difference between your study design and the one Brian Tissot and Leon Hallacher did on the Big Island.
- How important do you think scientific research should be to government policy makers deciding how to protect Hawaiian marine areas and marine life? What else should they consider in making these decisions?

Assessment Tools

- Design for monitoring study: Evaluate these on the basis of completeness using the list of elements in the Student Page “Design Your Own Monitoring Study,” scientific rigor, logic, and clarity of presentation.
- Journal entries

Design Your Own Monitoring Study

Natural Area Reserves (NARs) are among the most highly protected lands managed by the State of Hawai'i. They protect the best of what is left of the unique biological and geological resources of Hawai'i. The 'Āhihi-Kīna'u Natural Area Reserve is situated near the end of the road at Mākena on Maui, and is the only reserve in the Department of Land and Natural Resources (DLNR) system that includes a marine section as well as a land section. It is one of only two areas on Maui where fishing is restricted.

Within the reserve are the only three miles (4.8 kilometers) out of 120 total miles (193 kilometers) of Maui coastline that are totally protected, where no type of fishing, collecting of any marine life, or motorized vessel is allowed.

'Āhihi-Kīna'u Natural Area Reserve is an example of what is often called a "marine protected area" or MPA. MPAs are parts of the ocean that have legal restrictions on fishing, collecting, and other human activities that directly affect populations of fish and other marine life. There are many ways to manage marine protected areas. Some are closed to fishing or collecting altogether. Others have restrictions about the kind of gear that can be used. Still others limit fishing to certain species.

The basic ideas behind MPAs are that:

- MPAs may provide a refuge for fish, a protected area where they can exist in natural abundance without direct pressure from humans collecting or fishing for them.
- MPAs may provide a "source" area for fish and other marine life. Population levels may be higher inside MPAs than outside them. MPA supporters believe that populations in fishing grounds and other areas outside the MPAs will grow as larvae and fish "spill over" from the MPA.
- MPAs provide places to study recovery from prior fishing and/or collecting pressure.
- MPAs, like wilderness areas, may provide places to study intact natural communities, relatively undisturbed by human activities.

How Well Protected is 'Āhihi-Kīna'u?

The reserve is designed to be a marine protected area. The following activities are prohibited by law in the reserve:

a) To remove, injure, or kill any form of plant or animal,
b) To introduce any form of plant or animal life, or
c) To operate, anchor, or moor any motorized vessel.

However, reality is different than the law envisions. Although fishing and motorized vessels are prohibited in the reserve, illegal fishing still happens. The area is flanked on one side by La Pérouse Bay, where fishing is allowed, but the reserve is a prime spot for poachers anyway, many of whom enter the reserve in motorized vessels.

So, for researchers and natural resource managers, it is difficult to know just how well 'Āhihi-Kīna'u is working as a marine protected area. It is a challenge to interpret the results of monitoring and observations such as the following:

Image: Maui Recreation Map, *State of Hawai'i*

1) According to 1998 surveys, populations of some reef fish in the reserve have declined in variety and abundance, in comparison to surveys done in 1972, many years before the reserve was formed, and

2) '*Opihi* (limpets) are scarce along much of the coastline.

It is difficult to trace the causes of problems such as these because, although 'Āhihi-Kīna'u is supposed to be a protected area, people and illegal activities could be contributing. And that kind of illegal activity is not easy to monitor, especially along the reserve's rugged and remote lava coastline.

What's Really Going On Here?

Imagine that you are a scientist—perhaps Leon Hallacher or Brian Tissot—and the Department of Land and Natural Resources has asked you to help them monitor populations of fish in the reserve and determine the cause of the decrease in abundance of many fish species between a 1972 fish survey and one performed in 1998.

Some scientists believe that the decline in fish abundance and variety in the reserve is linked to the destruction of much of the finger coral habitat in powerful storms such as Hurricane 'Iniki (1992) and Iwa (1982). Others believe that illegal fishing has played an important role in decreasing fish abundance in the area.

Your job is to design a study to provide more information about:

1) Why the changes in abundance of many fish species has happened, and
2) Whether fish diversity and abundance seem to be recovering or declining since 1998.

As background, read the article from the DLNR-Division of Aquatic Resources newsletter, *Current Line* (April 1999) that follows. Then design a study that will provide information about the two goals listed above. As you design your study, don't forget you have access to a pool of willing and able university students who would love the chance to be part of this project. As in the Tissot and Hallacher study, they can help you collect data in the field.

Assignment

Write a study proposal including these seven elements:

1) **Title**

2) **Name of investigator(s)**

3) **Brief project background**

4) **Purpose and objectives**
   Questions to ask yourself:
   - Why are you doing this study?
   - What do you plan to accomplish?

5) **Hypothesis (or hypotheses)**
   - What results do you anticipate?
   - What do you think caused changes in fish abundance?

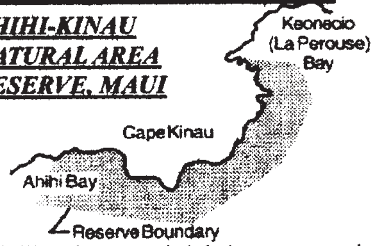
6) **Approach and methods**
   Questions to ask yourself:
   - What is your basic experimental design?
   - What kinds of areas do you want to study? (The Tissot/Hallacher study, for example, looked at "impact" areas and "control" areas, and defined what was meant by those terms and why they were included in the study.)
   - How long should the study be?
   - What is the geographic scope of the study?
   - Will you look at particular species of fish or other marine life? Will you look at adults, juveniles, and/or larvae? Why?
   - What assumptions are made in your research design? Do you need to add or do anything differently to gather evidence about the validity of these assumptions?

7) **Dissemination of findings**
   Questions to ask yourself:
   - Who should receive the information generated by this study? Why?
   - In what form should this information be disseminated?

From Hawai'i Division of Aquatic Resources, "Current Line" newsletter, April 1999.

INSHORE PROJECTS

AHIHI-KINAU NATURAL AREA RESERVE, MAUI



Ahihi-Kinau shore waters include the waters seaward of Cape Kinau a distance of 2000 to 3000 feet as shown above

The Ahihi-Kinau Natural Area Reserve (NAR), set on the last historic lava flow on Maui, was established in 1973. Ahihi-Kinau contains five natural communites including anchialine pools with a high diversity of rare Hawaiian shrimps (i.e. 'Ōpae'ula), a unique coastal lava tube community that provides habitat for native Hawaiian cave animals, and 900 acres of nearshore waters off Cape Kinau. NARs are different from Marine Life Conservation Districts (MLCDs) in that these areas are prime examples of relatively unmodified/unaltered native ecosystems which are set aside to protect "the best of what's left" of Hawaii's unique native environments. Therefore, fishing or taking of marine life is NOT ALLOWED.

Surveys done in 1972 by the Division of Fish and Game (now known as Division of Aquatic Resources) staff revealed dense growths of finger corals (Porites compressa) at 4 out of 6 survey sites along with a good diversity of fish species. In 1998 (26 years later), these same areas were again surveyed with some notable results. Fish populations in the remonitored areas appear to have decreased from 1364 fish per acre in 1972 to 962 fish per acre in 1998. The following tables give some examples on the differences between the numbers of specific fish seen in 1972 and 1998 at Ahihi-Kinau:

Fish that have increased or barely changed (<5%) in numbers per acre

Fish	*1972 Survey Numbers*	*1998 Survey Numbers*	*Diet*
C. strigosus (kole)	185	177	algae
C. vanderbilti (black-fin damsel)	72	98	zooplankton, copepods
A. nigofuscus (lavendar tang)	18	180	filamentous algae
P. multifasciatus (moana)	29	60	small crabs, fish, shrimp

Fish that have decreased (6% to 900%)) in numbers per acre

Fish	*1972 Survey Numbers*	*1998 Survey Numbers*	*Diet*
C. ovalis (blue damsel)	100	6	wide variety (shrimps, crustacean larvae, worms, fish eggs, etc.)
M. flavolineatus (white weke)	92	10	wide variety
A. abdominalis (mamo)	91	22	algae, zooplankton, crustaceans
D. albisella (aloiloi)	67	10	wide variety
M. vanicolensis (red weke)	67	22	echinoderms, worms, crustaceans
C. hanui (chocolate dip damsel)	64	24	"
T. duperrey (saddleback wrasse)	64	48	echinoderms, worms, crustaceans
Z. flavescens (yellow tang)	57	38	algae

As you can see, most of the fish appear to have decreased in numbers from 1972. DAR staff conducting the re-monitor surveys in 1998 did not observe the dense growths of finger corals as it was noted on 4 out of the 6 original survey sites in 1972. Instead of lush coral beds, the habitat in these areas now consist mostly of coral rubble. Since finger corals are very fragile, it is speculated that powerful storms like Hurricane Iniki (1992) and Hurricane Iwa (1982) caused the destruction of these vast coral beds within the last 26 years. The apparent loss of this finger coral habitat may explain the observed changes in fish populations.

Since the habitat now consists of coral rubble, this provides a lot of surface area for fine algal growth and other organic matter, which is an excellent food source for fishes such as the kole and lavendar tang. As a result, you can see from the previous tables that the numbers for these fish have either increased or remained relatively stable. This kind of coral rubble habitat may not have a wide variety of the larger invertebrates, but animals such as small shrimp, crabs, copepods, and other zooplankton can thrive providing a food source for fish like the black-fin damsel and moana, whose numbers have also increased. Most of the other fish whose numbers have decreased require a wider variety in diet than what can be found in coral rubble habitat. These fish probably moved into areas that are able to provide the right kind of diet for them, such as areas with richer coral growth. In addition to food, the more branching type corals provide shelter for juvenile fishes such as the yellow tang and aloiloi.

The mystery of Mother Nature is in Her continuing evolutionary ways, finding balance for all of Earth's natural resources. We can only monitor and observe these forever changing situations, as in the case of Ahihi-Kinau NAR. However, all is not lost in Ahihi-Kinau as wherever Mother Nature takes away, She always provides for someplace else. Additional surveys in 1998 along the shoreline of Ahihi-Kinau NAR revealed fish populations in quantities and diversity similar to many of the State's Marine Life Conservation Districts (MLCDs):

Comparison of Fish Counts in Ahihi-Kinau (inshore) to Other MLCDs in Terms of Numbers per Acre and Species Diversity

MLCD Location	*Date of Survey*	*Number of Fish per Acre*	*Number of Species Seen*
Honolua Bay, Maui	10/97	3764	76
Hanauma Bay, Oahu	5/97	3257	67
Ahihi-Kinau (inshore), Maui	**2/98**	**2839**	**83**
Manele-Hulo-poe, Lanai	10/97	2686	86
Molokini Shoals, Maui	10/97	2034	92

Top Ten Most Abundant Species Observed Along Shoreline Surveys of the Ahihi-Kinau NAR in 1998

Rank	*Fish Species*	*Number of Fish Per Acre*
1	C. strigosus (kole)	684
2	A. nigrofuscus (lavendar tang)	478
3	Z. flavescens (yellow tang)	282
4	C. vanderbilti (blackfin dam-sel)	194
5	A. achilles (achilles tang)	185
6	M. niger (humu ele ele)	121
7	T. duperrey (saddle-back wrasse)	41
8	Family Scari-dae (Uhu)	34
9	N. lituratus (clown tang)	30
10	A. sordidus (kupipi)	25

Although the resources are not what they were once described in the remonitored areas in Ahihi-Kinau, the shoreline fishery resources appear to have "weathered the storm". This is excellent news which means that areas like Ahihi-Kinau NAR can serve to provide the fishery stocks needed to spawn and restock other nearby areas.

Since fishing is not allowed within the boundaries of the Ahihi-Kinau NAR, you can clearly see that overfishing is not always the only factor that can contribute to declines in fish populations. Changes in habitat, such as those caused by natural disasters like hurricanes or man-made influences such as non-point source pollution and urban runoff, can also change the habitat causing fish populations to fluctuate. In the case of natural disasters, Mother Nature can always take care of Herself. The rest of us have to do our part to conserve and take care of our ocean resources by taking only what we need and limiting what we put into our ocean environment. You never know what may cause a fish or any other marine animal species to decline or increase.

Activity #4

Marine-Management Research Projects

Materials & Setup

- Student Page “Marine Management Research Projects—Suggested Topics” (pp. 54-56)

Instructions

1) Have students select a research topic related to marine management issues on Maui or around the state of Hawai‘i. They may use ideas from the Student Page “Marine Management Research Projects—Suggested Topics” or come up with their own.

2) Students should use a variety of sources to research their topics and develop a report using the media of their choosing.

Assessment Tools

- Student research reports

Marine-Management Research Projects -- Suggested Topics

There are many interesting research topics having to do with how people manage the marine environment and the species that live there. This background sheet suggests a handful of topics for which information is readily available.

Possible Research Topics

1) Marine Protected Areas

Protected areas are parts of the marine environment that have limits placed on how people can use them. In some marine protected areas (or refuges), fishing is not allowed at all. In others, fishing is limited to certain types of gear or certain species. Protected areas are designed to give marine plants and animals a break from human pressure. Research topics include the following:

- How and why are marine protected areas used in Hawai‘i? Where they have been used, have they been effective? Why or why not?

- How and why are marine protected areas used elsewhere in the world? Have they been effective? Why or why not?

- What do experts say about how to make marine protected areas effective?

- Under the traditional Hawaiian system governing fishing in the waters around the islands, certain areas were declared *kapu*, or forbidden, for periods of time to allow populations of marine life to recover from fishing pressure. These *kapu* areas were essentially marine protected areas. Research the traditional Hawaiian management system, as well as other islands where similar traditional systems are still used to manage coral reefs.

- What is the current status of Molokini Island and its surrounding waters? Is it a protected area of any variety? What regulations are in place to protect the surrounding coral reefs from damage by recreational boaters, snorkelers, and divers? What is being done to protect the coral reefs around Molokini?

2) Aquaculture

From the time of the ancient Hawaiians, people have been growing fish and other marine life for food. Along the coastlines of the islands, you can see the remnants of Hawaiian fishponds, some of which have been restored.Today, aquaculture operations raise fish for food and to restock fish into parts of the ocean that have been overfished. There is even experimentation with raising fish for the aquarium trade in aquaculture operations. Research topics include the following:

- How were fishponds constructed, used, and managed in early Hawaiian times? Which species were grown in these ponds? Which parts of Hawaiian society were fed by the marine life from these ponds? What is being done to restore fishponds on Maui or elsewhere in the Hawaiian Islands? Are there traditional fishponds in use today?

- What are some current examples of aquaculture on the Hawaiian Islands? Describe them as well as similarities and differences between modern aquaculture and how it was practiced by early Hawaiians.

- What are some of the potential benefits and problems associated with aquaculture? For example, what are the possible effects on water quality, wild fish populations, or human food supply?

3) Managing Marine Fishing

People use the abundant marine life here for many purposes. Some people fish for their own food, some fish commercially, and others make a living on sport-fishing charter boats. Making sure that there are enough fish and different kinds of fish to satisfy all of these uses is one job of government fishery managers. Research topics include the following:

- Which are the main species fished for commercially or for food or sport? Describe the species, their habitats, and how they are fished for. What is the status of populations of these fish in the waters around the Hawaiian Islands?

- Which kinds of food and sport fish were introduced on purpose? Why? What effect has their introduction had on native marine plants and animals?

- What is being done in Hawai‘i to increase populations of fish that are valuable for food or sport fishing? Which methods seem most effective? Least effective? Why? Research and explain other approaches you think might work well.

- What rights do native Hawaiian people have to fish and collect marine life for subsistence purposes? Describe some of the issues and concerns related to this topic, perhaps focusing on subsistence fishing that is allowed at ‘Āhihi-Kīna‘u Natural Area Reserve.

4) Protecting Threatened or Endangered Marine Species

Many marine species are protected by laws and regulations. Some of these rules are designed to protect species that are in danger of extinction. Others are designed to keep species from becoming endangered or threatened with extinction. Conservation efforts help protect many species, regardless of whether they are in danger of extinction. Research topics include the following:

- Pick a species or a type of plant or animal that you are interested in. What is the status of that species and what, if anything, is being done to protect it? (In general, there is more information available on species that are on the federal endangered species list than for species that are not endangered. Endangered Hawaiian marine species include hawksbill and green sea turtles, humpback whales, and Hawaiian monk seals.)

- What habitat conservation efforts are helping to protect endangered species and other species in the oceans around Maui and the other Hawaiian Islands? Research what is happening at the Hawaiian Islands Humpback Whale National Marine Sanctuary or the work of coral reef protection groups on Maui.

- What major laws and treaties are in place to protect endangered species? Research the Endangered Species Act, the Marine Mammal Protection Act, or the Convention on International Trade in Endangered Species of Wild Fauna and Flora. How do these laws help protect marine species found in Hawai‘i?

- What is the current status of U.S. Navy proposals to test and employ Low Frequency Active Sonar in waters around the Hawaiian Islands? What arguments are (or were) made for and against this proposal?