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

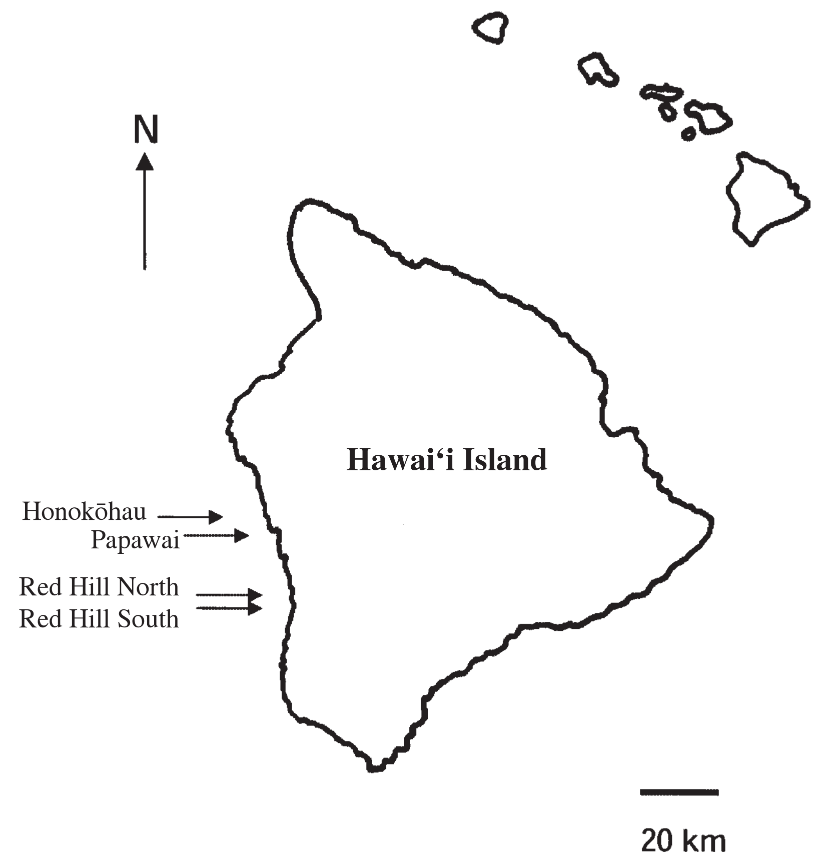

Figure 1. Map of study sites located on the island of Hawai'i

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.

References

Albaladejo, V. D., and V. T. Corpuz, "A Market Study of the Aquarium Fish Industry of the Philippines: An Assessment of the Growth and the Mechanics of the Trade," *Proceedings of the 4th International Coral Reef Symposium*, Vol. 1, 1981, pp. 75-81.

Andrews, C., "The Ornamental Fish Trade and Fish Conservation, *Journal of Fish Biology*, Vol. 37, Supplement A, 1990, pp. 53-59.

Clark, A. M., and D. Gulko, *Hawai‘i's State of the Reefs Report, 1998*, Department of Land and Natural Resources, Honolulu, 1999.

DLNR, *Hawai‘i Fishing Regulations,* Division of Aquatic Resources, Honolulu, 1996.

Edwards, A. J., and A. D. Shepherd, "Environmental Implications of Aquarium-Fish Collection in the Maldives, with Proposals for Regulation," *Environmental Conservation*, Vol. 19, 1992, pp. 61-72.

Grigg, R. W., "Hawaii's Coral Reefs: Status and Health in 1997, the International Year of the Reef," in R.W. Grigg and C. Birkeland (eds.), *Status of Coral Reefs in the Pacific*, University of Hawai‘i Sea Grant College Program, Honolulu, 1997, pp. 59-72.

Hallacher, L. E., and B. N. Tissot, “QUEST: Quantitative Underwater Ecological Survey Techniques: A Coral Reef Monitoring Workshop,” *Proceedings of the Hawai‘i Coral Reef Monitoring Workshop*, Department of Land and Natural Resources, Honolulu, 1999.

Katekaru, A., “Regulations of Tropical Fish Collecting,” *Working Papers No. 34*, Hawai‘i Sea Grant College Program, Honolulu, 1978, pp. 35-42.

Miyasaka, A., *Status Report, Aquarium Fish Collections, Fiscal Year 1993-1994*, Division of Aquatic Resources, Honolulu, 1994.

Miyasaka, A., *Status Report, Aquarium fish Collections, Fiscal Year 1994-95*, Division of Aquatic Resources, Honolulu, June 1997.

Randall, J. E., “Collecting Reef Fishes for Aquaria,” in B. Salvat (ed.), *Human Impacts on Coral Reefs: Facts and Recommendations*, Antenne Museum EPHE, French Polynesia, 1987, pp. 29-39.

Russell, S. H., “Coral Reef Conservation and Management: Providing Scientific Training to the Community,” *Proceedings of the 8th International Coral Reef Symposium*, Vol. 2, 1997, pp. 2087-2088.

Sadovy, S., “A Preliminary Assessment of the Marine Aquarium Export Trade in Puerto Rico,” *Proceedings of the 7th International Coral Reef Symposium,* Vol. 2, 1992, pp. 1014-1022.

Sale, P. F., and W. A. Douglas, “Precision and Accuracy of Visual Census Techniques for Fish Assemblages on Coral Reef Patch Reefs,” *Env. Biol. Fish.*, Vol. 6, 1981, pp. 333-339.

Taylor, L. R., “Tropical Reef Fish Management: Issues and Opinions,” *Working Papers No. 34*, Hawai‘i Sea Grant College Program, 1978, pp. 3-5.

Walsh, W. J., “Aquarium Fish Collecting: Promise or Problem?” *Working Papers No. 34*, Hawai‘i Sea Grant College Program, 1978, pp. 8-12.

Whitehead, M. J., E. Gilmore, P. Eager, P. McMinnity, W. Craik, and P. Macleod, *Aquarium Fishes and Their Collection in the Great Barrier Reef Region*, Great Barrier Reef Marine Park Authority Technical Memorandum GBRMPA-TM-13, 1986.

Wood, E., *Exploitation of Coral Reef Fishes for the Aquarium Trade*, Report to Marine Conservation Society, United Kingdom, 1985.

Young, L. G. L., “Sustainability Issues in the Trade for Wild and Cultured Aquarium Species,” in *Marketing and Shipping Live Aquatic Products, ’96, Seattle, Washington, 13-15 October, 1996* (conference proceedings), Northeastern Regional Agricultural Engineering Service Cooperative Extension, Ithaca, New York, 1997, pp. 145-151.

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?)