Survey of Marine Resources at Kīpahulu, Maui 2019

By

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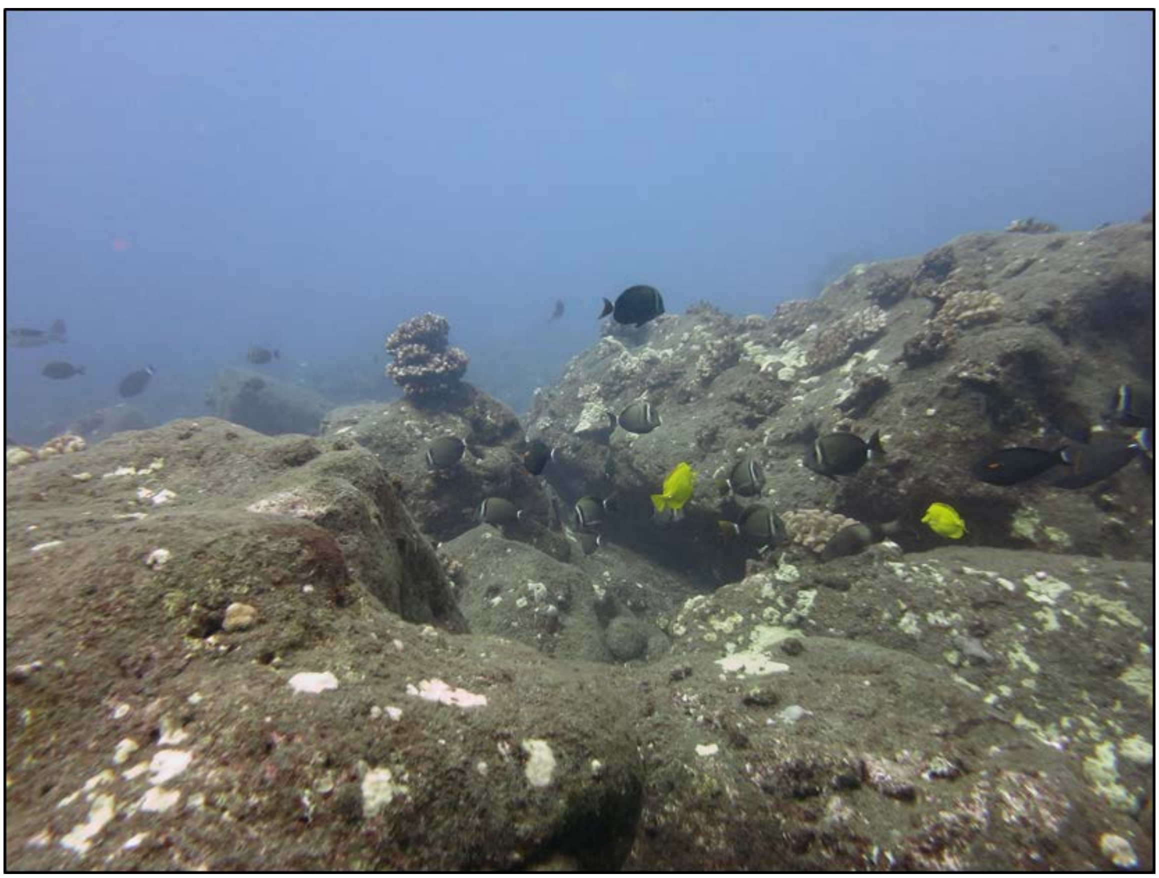

January 28, 2020

List of English Common, Hawaiian, and Scientific Names
of Species Included in this Report

Common Name	Hawaiian Name	Scientific Name
Crust coral	Ko‘a	*Leptastrea purpurea*
Transverse coral	-	*Leptastrea transversa*
Rice coral	‘Āko‘ako‘a	*Montipora capitata* (=*verrucosa*)
Blue-gray zooanthid	-	*Palythoa caesia*
Antler coral	-	*Pocillopora eydouxi*
Cauliflower coral	Ko‘a	*Pocillopora meandrina*
Brigham's coral	-	*Porites brighami*
Finger coral	Pōhaku puna	*Porites compressa*
Lobe coral	Pōhaku puna	*Porites lobata*
Hump coral	-	*Porites lutea*
Leather coral	-	*Sinularia* spp.

Common Name	Hawaiian Name	Scientific Name
Green jobfish	Uku	*Aprion virescens*
Stareye parrotfish	Pōnuhunuhu	*Calotomus carolinus*
Peacock grouper	Roi	*Cephalopholis argus*
Spectacled parrotfish	Uhu ‘ahu‘ula	*Chlorurus perspicillatus*
Bullethead parrotfish	Uhu	*Chlorurus spilurus*
Goldring bristletooth	Kole	*Ctenochaetus strigosus*
Bluestriped snapper	Ta‘ape	*Lutjanus kasmira*
Blacktail snapper	To‘au	*Lutjanus fulvus*
Yellowstripe goatfish	Weke ‘a	*Mulloidichthys flavolineatus*
Yellowfin goatfish	Weke ‘ula	*Mulloidichthys vanicolensis*
Bluespine unicornfish	Kala	*Naso unicornis*
Island goatfish	Munu	*Parupeneus insularis*
Manybar goatfish	Moano	*Parupeneus multifasciatus*
Sidespot goatfish	Malu	*Parupeneus pleurostigma*
Whitesaddle goatfish	Kūmū	*Parupeneus porphyreus*
Palenose parrotfish	Uhu	*Scarus psittacus*
Ember parrotfish	Uhu ‘ele‘ele	*Scarus rubroviolaceus*
Yellow tang	Lau‘ipala	*Zebrasoma falvescens*

Note on names:
This report uses English common names to allow for easier reading for those not familiar with scientific names. English common names were selected for use over Hawaiian names to avoid confusion: a single Hawaiian name can often apply to multiple species. Hawaiian names were obtained primarily from three sources: Randall (2007) for fish, and Hoover (1998) and Bernice P. Bishop Museum's for invertebrates.

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Cover image: A mixed school of suregonfishes feed on turf algae at Kīpahulu.

Summary of Findings

The Kīpahulu community, through their non-profit Kīpahulu Ohana, has submitted a proposal to establish a Community-based Subsistence Fishing Area (CBSFA) within the Kīpahulu moku, with the expressed goal to perpetuate the traditional practices and subsistence lifestyle of the residents. In 2010 and again in 2013, the Ohana invited The Nature Conservancy's (TNC) marine monitoring team to conduct biological assessments of the coral reefs of Kīpahulu. The monitoring team collected data that proved valuable to developing the CBSFA proposal and could serve as part of a baseline assessment of these reefs. In 2019, TNC's marine monitoring team was again invited to survey Kīpahulu's reefs to update and strengthen the baseline data for the area.

Between September 30 and October 2, 2019, TNC collected fish and benthic data at 36 randomly-selected sites along 9.2 km of nearshore reef within the Kīpahulu moku. Kīpahulu's benthic assemblage was dominated by turf algae. Coral cover was low (6.4% of the bottom) and dominated by cauliflower and lobe corals, two species typical of wave-exposed reefs in Hawaiʻi. The benthic assemblage in 2019 did not significantly differ from that present in 2010.

The fish assemblage had high biomass (weight), with surgeonfish, goatfish, wrasses, snappers, and parrotfish contributing most to the total biomass. Species prized by fishers, called "resource fish" in this report, and ecologically important prime spawners (the largest individuals of resource fish species) were as abundant at Kīpahulu as at areas closed to fishing on Maui, suggesting the fish assemblage at Kīpahulu is subject to relatively low fishing-related impacts. However, a broader context is needed to fully understand fishing pressure on Maui and at Kīpahulu. Wide-ranging species such as jacks are subject to "regional" fishing pressure, which can reduce their biomass even within protected areas. Compared to remote reef areas like the Northwestern Hawaiian Islands, areas closed to fishing in the main Hawaiian Islands show considerable, fishing-related impacts. Within this context, however, fishery resources at Kīpahulu are still in remarkably good condition compared to other areas on Maui and throughout the main Hawaiian Islands.

While fish abundance and biomass were comparable to areas closed to fishing on Maui, elders within the Kīpahulu community describe historically abundant reefs, making it apparent that Kīpahulu has experienced an historical decline in fishery resources over the past half century. These declines, which are difficult to quantify, are likely associated with local land-based stressors and fishing occurring primarily outside the Kīpahulu community, and it's unclear if additional fishing regulations at Kīpahulu will result in significant increases in fish biomass. However, additional fishery regulation would likely prevent future declines if Kīpahulu's population increases or if fishing access increases above current levels.

Introduction

The Kīpahulu community, through their non-profit Kīpahulu Ohana, has submitted a proposal to the Hawaiʻi Department of Land and Natural Resources to establish a Community-based Subsistence Fishing Area (CBSFA) within the Kīpahulu moku, with the expressed goal to perpetuate the traditional practices and subsistence lifestyle of the residents (Kīpahulu Ohana 2019). The proposed CBSFA would encompass the marine waters and submerged lands of Kīpahulu moku from Kālepa to Puaʻaluʻu, and extending from the high water mark to the 60 meter (180 feet) depth contour. Within the CBSFA boundary, the community has proposed a variety of catch, size, and gear limits to address unsustainable and inappropriate harvests, and overly efficient gear and methods.

In 2010 and again in 2013, Kīpahulu Ohana invited The Nature Conservancy's (TNC) marine monitoring team to conduct biological assessments of coral and fish on the reefs of Kīpahulu. These surveys produced data that proved valuable to developing the CBSFA proposal and could serve as part of a baseline assessment of these reefs. In 2019, TNC's marine monitoring team was again invited to survey Kīpahulu's reefs to update and strengthen the baseline data for the area. This report describes the findings from surveys of the Kīpahulu reef conducted between September 30 and October 2, 2019 by TNC. These findings are intended to support community-led conservation efforts by communicating the status and condition of the marine resources on the Kīpahulu reef to the Kīpahulu community, stakeholders, and other decision makers, and by helping create a baseline against which the success of future conservation efforts can be measured. The community is free to use the information found in this report in its original form or to summarize the findings into a shorter format.

Site Description

The Kīpahulu moku is located on the trade-wind exposed southeast side of Maui, south of Hāna and east of Kaupō, and is subject to rough sea conditions for much of the year. While archeological evidence suggests the Kīpahulu moku once supported an extensive human population, the coastline today is lightly developed, with a small community of approximately 150 people. Upland is mostly forested with some small-scale agriculture, but feral cattle, goats, and pigs may be abundant and contributing to native forest degradation and soil erosion. Historically, Kīpahulu had extensive taro, sugar cane and ranching operations, which resulted in significant runoff into the coastal marine environment, and runoff may still be a problem along sections of the Kīpahulu shoreline (Kīpahulu Ohana 2019). While there are 10 streams in the moku, only ʻOheʻo and Puaʻaluʻu streams have continuous water flow year-round, and the remaining eight are intermittent, having water flow during the wet season.

Following consultation with the Kīpahulu community, TNC expanded the survey area in 2019 from previous years (2010 and 2013) to include the coral reef area across the entirety of the Kīpahulu moku, covering approximately 9.2 km (5.7 miles) of shoreline (Figure 1). The 2019 survey area extended from shore to 15 m deep and from Kaʻāpahu Bay in the east to Puaʻaluʻu Stream, just north of ʻOheʻo Gulch. The marine environment within the survey area is characterized by seasonal high wave energy, and freshwater inputs from streams and underwater

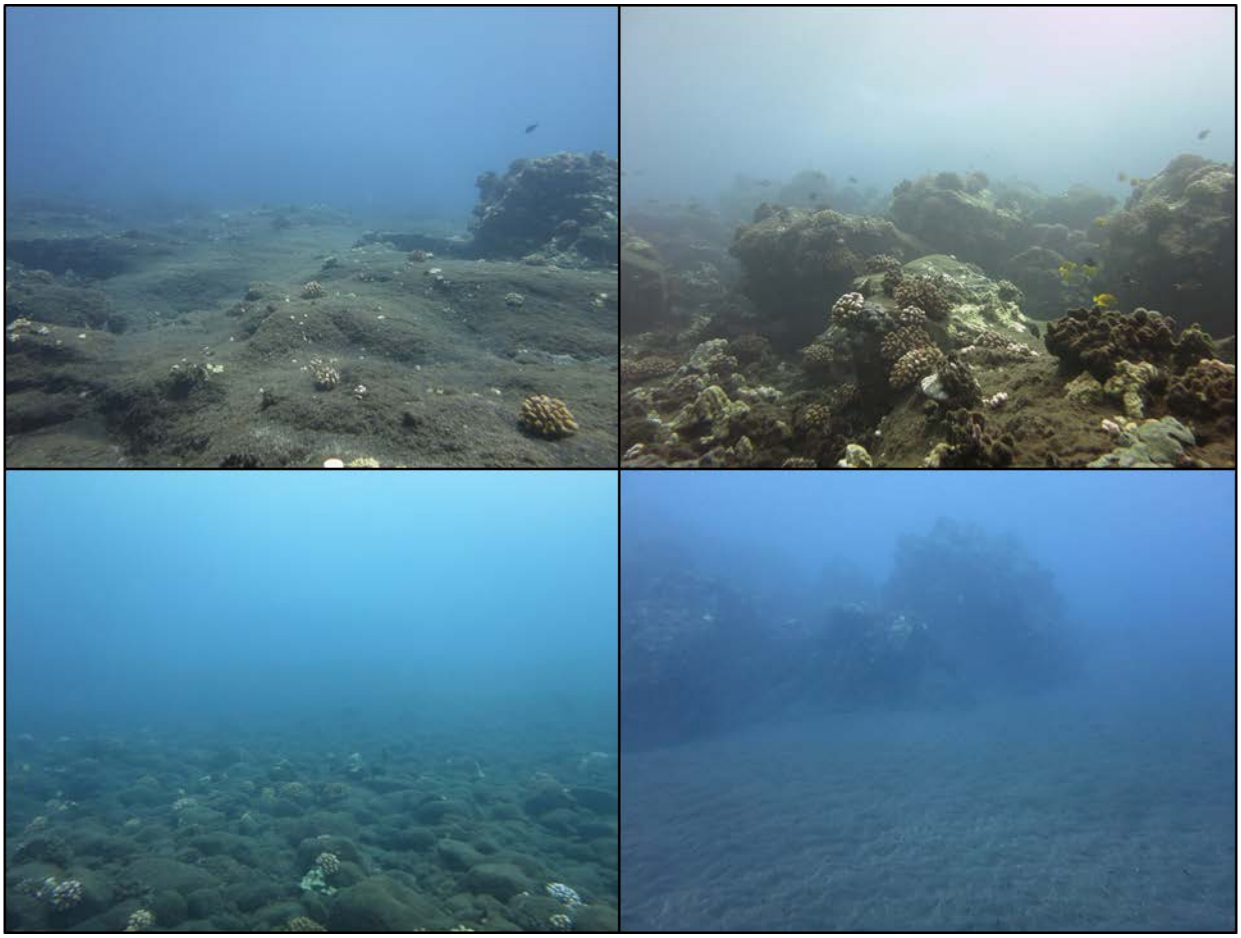

Plate 1. The exposed reefs of Kīpahulu are comprised primarily of basalt boulders and substratum covered with sparse coral growth (top photos) and areas of cobble and unconsolidated sand (bottom photos).

seeps. The bottom within the survey area is primarily basalt boulders and substratum covered with sparse coral growth, but with areas inside embayments often comprised of unconsolidated sand or cobble.

Survey Methods

Between September 30 and October 2, 2019, TNC collected fish and benthic data at 36 randomly-selected[1] sites within the survey area (Figure 1). All sites were between 3 and 15 m depth and on predominately hardbottom. Locational information (latitude/longitude) and other metadata for all survey sites has been compiled in Appendix A.

[1] Random sites were selected in order to get an unbiased measure of the community across the Kīpahulu survey area. Using a non-random site selection method, such as selecting sites known to have high fish abundance, would provide a skewed or biased assessment of the Kīpahulu's reef community.

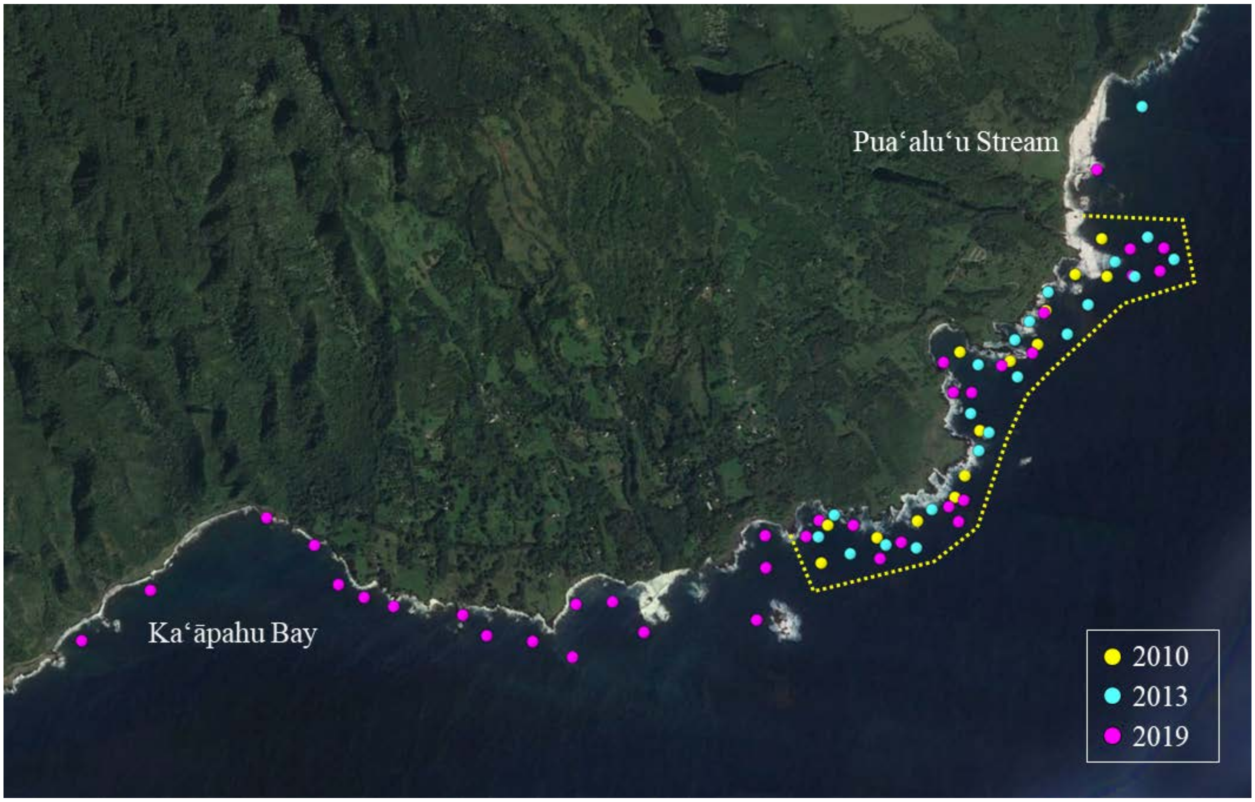

Figure 1. Sites surveyed by TNC at Kīpahulu, Maui in 2010, 2013, and 2019. Previous reef surveys were restricted to the reef area between Kalena Stream to just north of 'Ohe'o Gulch (dotted yellow line), which is referred to as the "2010-2013 area" in this report.

Survey teams navigated via small, motorized boat to each predetermined site using a Garmin GPS unit. Once on site, divers on scuba were deployed and descended directly to the bottom, where they established two transect start-points approximately 10 m apart. From each start-point, divers deployed separate 25-m transect lines along a predetermined compass heading, resulting in two transect lines running parallel to each other. If the pre-determined compass bearing resulted in a large change in depth, the bearing was altered such that the transect followed the contour at the depth of the start point. All data collection was conducted along one or both transect lines by trained and experienced scientific divers who had been calibrated to reduce surveyor variability. The specific survey methods for each type of data collected are discussed in detail below.

Benthic Cover

At each survey site, photographs of the bottom were taken every meter along one 25-m transect line using a Canon Powershot camera or equivalent in an underwater housing mounted on a PVC monopod. The white-balance of the camera was adjusted prior to photographing each transect to improve color quality. This generated 25 images for each survey site, with each photo covering approximately 0.8 x 0.6 m of the bottom.

Plate 2. A diver prepares to roll and conduct a fish survey (left photo). A surveyor collects positional metadata on a Kīpahulu survey site using a handheld GPS (right photo).

Twenty randomly-selected photographs from each transect were analyzed to estimate the percent cover of coral, algae, and other benthic organisms. Photos were analyzed using Coralnet, an online repository and resource for benthic image analysis maintained by the University of California, San Diego (Beijbom *et al.* 2015). Thirty random points[2] were overlaid on each digital photograph, and the benthic component under each point was identified to the lowest possible taxonomic level, primarily individual coral species, algae at higher taxonomic resolution (*e.g.*, red, green, brown, turf, and crustose coralline, but sometimes genera), and abiotic substratum type (*e.g.*, sand, rubble, etc.). All photographs were processed by the same analyst to reduce potential observer variability.

<u>Benthic Topography</u>

The topographic complexity of the bottom at each site was measured using an index of rugosity calculated along the first 10 m of the same transect used for benthic photographs. Rugosity was calculated by dividing the length of brass chain necessary to contour the bottom by the 10-m transect length (McCormick 1994). For this index, a value of one represents a flat surface with

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[2] The number of points analyzed on each photograph (30 points) and the number of photographs at each site (20 photographs) were selected to optimize effort and represent the lowest sampling effort necessary to achieve adequate statistical power to detect spatial and temporal differences in benthic cover.

no topographic relief, and increasing values represent more topographically complex substrata. Rugosity values for all sites can be found in Appendix A.

Coral Reef Fish Biomass

While slowly deploying the parallel 25-m transect lines, divers identified to species and sized to the nearest centimeter all fishes within and passing through a 5-m wide belt along the transect. Divers took between 10 and 15 minutes to complete a single survey. Individual fish biomass (*i.e.*, wet weight) was calculated using the fish length and size-to-weight conversion parameters from FishBase (Froese and Pauly 2010) or the USGS Hawaiʻi Cooperative Fisheries Research Unit (HCFRU). Some species, such as eels (Family Muraenidae), cannot be reliably sized using non-intrusive visual surveys, so these species were counted but excluded from biomass estimates.

Fish data were pooled into several groups, including total (all) fish, fish family, resource fish[3] including a selected non-resource group for comparison, and prime spawners. Resource fish refer to fishes desirable for food, commercial activity, and/or cultural practices in Hawaiʻi (see Williams *et al.* 2008), whereas the selected non-resource fish are species not routinely targeted by fishers to a significant degree (Table 1). Nearly all fish species are taken by some fishers at some time in Hawaiʻi, therefore designating a fish species as either 'resource' or 'non-resource' is oftentimes difficult. These two groupings—resource fish and non-resource fish—are intended to represent the high and low ends of the fishing pressure continuum. Prime spawners are resource fishes larger than 70% of the maximum size reported for the species in Hawaiʻi. Fishes at the high end of their size range tend to be a disproportionately important component of the total stock breeding potential due to their high fecundity and higher larval survival compared to smaller breeding individuals (Williams *et al.* 2008). In addition, fishers preferentially target large resource fishes, making 'prime spawner' biomass a good indicator of fishing impacts.

Previous Surveys: 2010 and 2013

TNC surveyed a portion of the 2019 survey area in 2010 (14 sites) and 2013 (21 sites). This smaller survey area is referred to as the "2010-2013 area" (Figure 1) in this report. In 2019, 18 of 36 surveys sites were inside the 2010-2013 area. Previous surveys were conducted using identical methods as those in 2019 except the photo-analysis in 2010 was conducted using Coral Point Count with Excel extension (CPCe) developed by the National Coral Reef Institute (Kohler and Gill 2006). As with Coralnet, CPCe placed 30 random points over benthic photographs and a trained analyst identified the organism or benthic substratum under each point to the lowest possible taxonomic level. Where necessary, taxonomic categories from 2010 were combined to

[3] In other TNC reports, "resource fish" may be called "target fish;" the species comprising these groups are identical (see Table 1). In addition, TNC's use of the terms "resource" and "target" fish should not be confused with "target" species, as described in the Kīpahulu CAP (Kīpahulu Ohana 2012) or the Kīpahulu CBSFA Proposal (Kīpahulu Ohana 2019). While there may be overlap of species included in TNC's "resource" fish group (see Table 1) with those identified in the Kīpahulu CAP and CBSFA proposal, these groupings are not identical or interchangeable. We have chosen to use the "resource" species described in Table 1 to define those species most prized by fishers to facilitate comparison with other sites surveyed by TNC and other researchers statewide.

Table 1. Fish species comprising the seven resource species groups and the non-resource group used in this report. Groups are modified from Williams *et al.* (2008).

Resource Groups	
Surgeonfishes (Acanthuridae)	Apex
Acanthurus achilles	*Aphareus furca*
Acanthurus blochii	*Aprion virescens*
Acanthurus dussumieri	All Carangidae (jacks)
Acanthurus leucopareius	All Priacanthidae (big-eyes)
Acanthurus nigroris	All Sphyraenidae (barracuda)
Acanthurus olivaceus	
Acanthurus triostegus	Goatfishes (Mullidae)
Acanthurus xanthopterus	All
Ctenochaetus spp.	
Naso spp.	Parrotfishes (Scaridae)
	All
Wrasses (Labridae)	
Bodianus albotaeniatus	Soldier/Squirrelfishes(Holocentridae)
Cheilio inermis	*Myripristis* spp.
Coris flavovittata	*Sargocentron spiniferum*
Coris gaimard	*Sargocentron tiere*
Iniistius spp.	
Oxycheilinus unifasciatus	Others
Thalassoma ballieui	*Chanos chanos*
Thalassoma purpureum	*Cirrhitus pinnulatus*
	Monotaxis grandoculis

Non-resource	
Acanthurus nigrofuscus	*Chaetodon quadrimaculatus*
Acanthurus nigricans	*Chaetodon unimaculatus*
Chaetodon multicinctus	*Plectroglyphidodon* spp.
Chaetodon ornatissimus	*Stegastes* spp.
All wrasses, except those listed above	
All hawkfishes, except *Cirrhitus pinnulatus*	
All triggerfishes, except planktivorous species	

make them consistent with those used in 2019. For example, CCA in 2010 was subdivided into two morphological forms (smooth CCA and rough CCA), which were combined to make it consistent with the CCA in 2019. No benthic data was collected in 2013, otherwise, comparable data are available for all three years within the 2010-2013 area. Previous data were reanalyzed for this report and summary results presented here for 2010 and 2013 may vary slightly from those presented previously due to rounding and sites included. Site metadata for the 2010 and 2013 survey sites are available in Appendix A.

Results and Discussion

Benthic Assemblage

Current (2019) Condition

Thirteen benthic taxa, including eight species of coral, were observed at Kīpahulu in 2019. As found in previous surveys, coral cover was low, averaging 6.4 ± 0.9% of the bottom (Table 2), which is substantially lower than the average cover for reefs on West Maui (17.6 ± 1.3; Minton *et al.* 2020) and statewide (21.7 ± 1.6%; CRAMP 2008). The benthic assemblage at Kīpahulu was, however, consistent with that found on other wave exposed coastlines in Hawai‘i, where

Table 2. Mean (±SEM) percent cover of the bottom by major biological taxa and abiotic groups observed during the 2019 surveys on the Kīpahulu reef, Maui. The 2019 Kīpahulu survey area was comprised of reef area inside and outside the 2010-2013 area. See text and Figure 1 for more information.

Taxon/Group	Kīpahulu	Outside	Inside
Coral Total	6.4 ± 0.9	6.8 ± 1.2	6.0 ± 1.4
Cauliflower coral	3.8 ± 0.6	3.9 ± 0.9	3.7 ± 1.0
Lobe coral	2.3 ± 0.3	2.4 ± 0.5	2.2 ± 0.5
Rice coral	0.1 ± 0.1	0.2 ± 0.2	0.1 ± 0.1
Antler coral	0.1 ± 0.1	0.1 ± 0.1	0
Sandpaper rice coral	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Crust coral	<0.1	0.1 ± 0.1	0
Transverse coral	<0.1	<0.1	0
Finger coral	<0.1	<0.1	0
Brigham’s coral†	0	0	0
Hump coral†	0	0	0
Unidentified Porites†	0	0	0
Crustose Coralline Algae	3.9 ± 1.1	2.5 ± 0.6	5.2 ± 2.1
Macroalgae	0.2 ± 0.1	0.3 ± 0.1	0.2 ± 0.1
Other	0.2 ± 0.1	0.3 ± 0.2	<0.1
Zoanthid	1.0 ± 0.4	1.2 ± 0.5	0.9 ± 0.6
Turf Algae	75.0 ± 2.0	72.1 ± 3.3	77.8 ± 2.4
Abiotic Total	13.3 ± 2.2	16.8 ± 4.1	9.9 ± 1.7
Sand	12.3 ± 2.1	15.7 ± 4.0	9.1 ± 1.6
Rubble	0.9 ± 0.3	1.1 ± 0.5	0.8 ± 0.3
Pavement	<0.1	<0.1	<0.1
Dead Coral†	0	0	0

†Not present during the 2019 surveys but observed during 2010 surveys at Kīpahulu.

seasonal large-swell events prevent large coral populations from forming. Species diversity was low and dominated by turf algae (75.0 ± 2.0%), and most of the corals present were robust cauliflower (3.8 ± 0.6%) and lobe (2.3 ± 0.3%) corals, two species that survive well in rough sea conditions (CRAMP 2008). In addition, typical high energy species such as leather coral (*Sinularia* spp.) and the blue-gray zoanthid (*Palythoa caesia*) were observed at several sites. The benthic assemblage inside and outside the 2010-2013 area did not significantly differ (PERMANOVA; $F_{1,33}$=1.186; p=0.331).

Change Over Time

The benthic assemblage did not significantly differ between the 2010 and 2019 surveys (PERMANOVA; $F_{1,30}$=0.592; p=0.649). In both years, turf comprised ~78% of the benthic cover and total coral cover (~6%) and coral species dominance (cauliflower and lobe corals) were similar (Table 3). This finding is significant because numerous studies around the state have documented significant declines in coral cover over the past 5-10 years. For example, coral cover has declined on many west Maui (Minton *et al.* 2020) and west Hawaiʻi reefs (Kramer *et al.* 2016, Minton *et al.* 2018) since the early 2000s, and especially since 2014 and 2015, the last time Hawaiʻi experienced a series of mass coral bleaching events that affected reefs statewide (see below). Cauliflower coral was one of the most heavily impacted coral species in these bleaching events, with many areas around the state experiencing heavy mortality of this species; cauliflower coral cover in Kīpahulu, however, was unchanged from 2010 to 2019. This stability in the benthic assemblage at Kīpahulu suggests the reefs are displaying some degree of adaption to the local stressors (e.g., sediment loading), while showing resilience to regional and global ones.

Coral Bleaching

Since 2014, some degree of widespread coral bleaching has occurred nearly annually in the Hawaiian Islands, although the severity and extent has varied considerably from year to year. In 2014, severe bleaching was restricted primarily to reefs on Oʻahu (Bahr *et al.* 2015, Minton *et al.* 2015). In 2015, reefs on Maui (Field *et al.* 2019) and West Hawaiʻi (Kramer *et al.* 2016, Maynard *et al.* 2016) were particularly affected. From 2016-2018, bleaching was not as severe, but was observed at several reef locations in Hawaiʻi. In 2019, sea water temperature conditions were again elevated (NOAA Coral Reef Watch), and widespread bleaching was reported during the time frame in which these surveys were conducted at many locations around the state by both citizen scientists and coral reef professionals.

Survey teams observed extensive bleaching at Kīpahulu in 2019, with six of the eight coral species showing at least some paling. Sample sizes for all but the two most common species were too small to draw solid conclusions about coral tissue bleaching rates. Historically, cauliflower coral has fared poorly during severe bleaching events in Hawaiʻi, often experiencing high rates of tissue bleaching and colony mortality (Kramer *et al.* 2016, Maynard *et al.* 2016). At Kīpahulu, 45.2 ± 5.5% of the cauliflower coral tissue was bleached, a rate that is considerably lower than that observed on other reefs during the 2015 bleaching event. Lobe coral is often more tolerant of elevated temperatures, and at Kīpahulu 34.4 ± 4.5% of lobe coral tissue showed evidence of paling or severe bleaching.

Table 3. Mean (±SEM) percent cover of the bottom by major biological taxa and abiotic groups observed during the 2010 and 2019 surveys on the Kīpahulu reef, Maui. Cover estimates for 2019 were derived only from sites that occurred inside the 2010-2013 area. See text and Figure 1 for more information. Data from 2010 are from Minton *et al.* (2014).

Taxon/Group	2010	2019
Coral Total	6.6 ± 1.2	6.0 ± 1.4
Cauliflower coral	3.2 ± 0.6	3.7 ± 1.0
Lobe coral	3.0 ± 0.6	2.2 ± 0.5
Rice coral	0.1 ± 0.1	0.1 ± 0.1
Antler coral	0	0
Sandpaper rice coral	0.1 ± 0.1	0.1 ± 0.1
Crust coral	<0.1	0
Transverse coral	0	0
Finger coral	0.1 ± 0.1	0
Brigham’s coral	<0.1	0
Hump coral	<0.1	0
Unidentified Porites	<0.1	0
Crustose Coralline Algae	1.9 ± 0.5	5.2 ± 2.1
Macroalgae	0.6 ± 0.2	0.2 ± 0.1
Other	0.9 ± 0.5	<0.1
Zoanthid	0.3 ± 0.2	0.9 ± 0.6
Turf Algae	78.0 ± 2.5	77.8 ± 2.4
Abiotic Total	11.6 ± 2.0	9.9 ± 1.7
Sand	9.1 ± 1.9	9.1 ± 1.6
Rubble	2.3 ± 0.8	0.8 ± 0.3
Pavement	0.2 ± 0.1	<0.1
Dead Coral	<0.1	0

The full extent and severity of the 2019 bleaching is currently unknown, so it is difficult to contextualize the coral bleaching that occurred at Kīpahulu. It is possible that bleaching rates at Kīpahulu were lower than on other reefs in the state due to enhanced water mixing associated with its wave- and wind-exposed location. Information on coral bleaching during the 2015 event was not available for Kīpahulu, so bleaching severity is unknown. However, unlike most reefs that experienced severe bleaching in 2015, the coral cover at Kīpahulu has remained stable since 2010, suggesting that any mortality that may have occurred as a result of the 2015 bleaching event at Kīpahulu in 2015 was minor. It is not clear if the lack of significant coral mortality at Kīpahulu was a result of low bleaching prevalence and/or severity or if bleached corals had greater survival then at other locations. However, it is likely that environmental conditions (*i.e.*, exposure to wave energy), were a factor in their apparent resilience.

Fish Assemblage

Current (2019) Condition

In 2019, a total of 115 species representing 21 families of fish were observed at Kīpahulu (Table 4). Average total fish biomass was 87.4 ± 14.9 g/m^2. Surgeonfish (Acanthuridae), snappers

Table 4. Mean (±SEM) biomass (g/m^2) of fish by family observed during the 2019 surveys on the Kīpahulu reef, Maui. The 2019 Kīpahulu survey area was comprised of reef area inside and outside the 2010-2013 area. See text and Figure 1 for more information.

Fish Family	Kīpahulu	Outside	Inside
Surgeonfish (Acanthuridae)	43.0 ± 6.2	43.6 ± 9.7	42.4 ± 8.3
Snappers (Lutjanidae)	11.1 ± 3.7	16.1 ± 6.0	6.1 ± 4.4
Parrotfish (Scaridae)	6.9 ± 1.4	7.1 ± 2.3	6.8 ± 1.7
Wrasses (Labridae)	6.9 ± 1.0	4.5 ± 1.1	9.2 ± 1.5
Goatfish (Mullidae)	3.9 ± 1.3	5.0 ± 2.5	2.9 ± 1.0
Triggerfish (Balistidae)	3.2 ± 0.7	2.7 ± 0.9	3.7 ± 1.0
Butterflyfish (Chaetodontidae)	2.6 ± 1.5	1.1 ± 0.3	4.1 ± 3.0
Damselfish (Pomacentridae)	2.1 ± 0.7	2.8 ± 1.2	1.4 ± 0.5
Chub (Kyphosidae)	1.6 ± 1.1	2.7 ± 2.2	0.5 ± 0.4
Jacks (Carangidae)	1.4 ± 0.5	1.7 ± 0.8	1.0 ± 0.5
Squirrelfish (Holocentridae)	1.4 ± 0.7	0.9 ± 0.6	1.8 ± 1.3
Emperors (Lethrinidae)	1.3 ± 0.7	0.8 ± 0.4	1.7 ± 1.4
Moorish Idol (Zanclidae)	0.8 ± 0.3	0.8 ± 0.4	0.9 ± 0.5
Hawkfish (Cirrhitidae)	0.5 ± 0.1	0.6 ± 0.1	0.4 ± 0.1
Groupers (Serranidae)	0.3 ± 0.2	0.1 ± 0.1	0.5 ± 0.4
Pufferfish (Tetraodontidae)	0.2 ± 0.1	0.1 ± 0.0	0.3 ± 0.1
Filefish (Monacanthidae)	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Angelfish (Pomacanthidae)	<0.1	<0.1	<0.1
Trumpetfish (Aulostomidae)	<0.1	<0.1	<0.1
Boxfish (Ostraciidae)	<0.1	<0.1	<0.1
Blennies (Blenniidae)	<0.1	<0.1	<0.1
Porcupinefish (Diodontidae)†	0	0	0
Scorpionfish (Scorpaenidae)†	0	0	0
Lizardfish (Synodontidae)†	0	0	0
Eels (Muraenidae)‡	NA	NA	NA
Unidentified Fish‡	NA	NA	NA
Total Fish Biomass	87.4 ± 14.9	90.9 ± 17	83.9 ± 13.1

†Not present during the 2019 surveys, but observed during 2010-2013 surveys at Kīpahulu.
‡Counted, but biomass could not be estimated. See methods for more discussion.

(Lutjanidae), parrotfish (Scaridae), and wrasses (Labridae) contributed the most to fish biomass, accounting for ~77% of the total fish biomass. No differences were detected in the fish assemblage inside and outside the 2010-2013 survey (PERMANOVA; $F_{1,34}$=1.043; p=0.379). Similar to the benthic assemblage, this indicates that these reefs areas are part of a single larger reef area.

While no significant difference in fish assemblage structure was observed inside compared to outside the 2010-2013 area, some differences were noted. For example, average snapper biomass outside the 2010-2013 area was more than double that observed inside. The Kīpahulu community has expressed concerns about the abundance of introduced snapper. Outside the 2010-2013 area, introduced snapper comprised almost 63% of the snapper biomass, whereas inside, they were less abundant and comprised ~23% of the snapper biomass. Reasons for the spatial variability in the biomass of introduced snappers is not clear, but it could be related to small differences in habitat; *e.g.*, average percent cover of sand was slightly higher outside compared to inside the 2010-2013 (Table 1).

Total fish biomass at Kīpahulu in 2019 was greater than other areas open to fishing (*i.e.*, subject to no additional regulations beyond statewide fishing rules) in Maui Nui (Figure 2). Total fish biomass is correlated with human population density, shoreline access, and the level of fishing

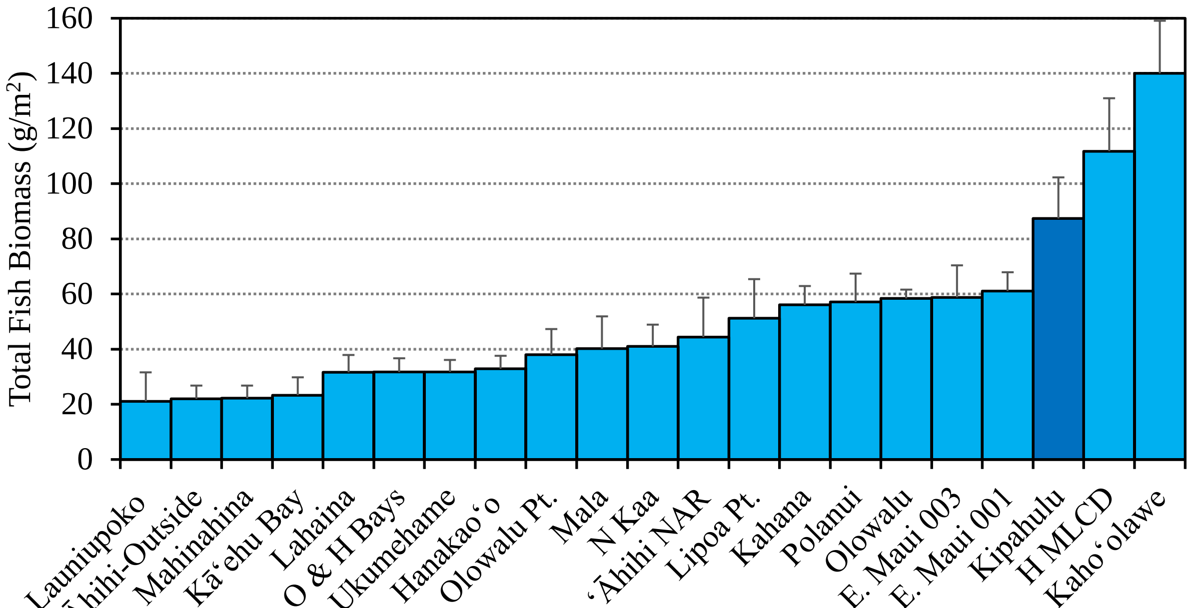

Figure 2. Total fish biomass at Kīpahulu in 2019 (dark blue bar) and 20 Maui Nui sites. All Maui Nui sites are "open" to fishing, except the ʻĀhihi-Kīnaʻu Natural Area Reserve (ʻĀhihi NAR), Honolua MLCD (H MLCD), and Kahoʻolawe. West Maui data were compiled by Minton *et al.* (2020), ʻĀhihi NAR and ʻĀhihi-Outside by Minton *et al.* (2016a), Kahoʻolawe by Minton *et al.* (2016b), and Kāʻehu Bay, E Maui 001, and East Maui 003 by TNC. Bars represent SEM. N Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays.

regulation (Friedlander *et al.* 2013, Friedlander *et al.* 2017). Easily accessible areas near population centers tend to have lower total fish biomass than more isolated areas and/or areas with greater fishery management. This pattern holds for the sites on Maui (Minton *et al.* 2020). For example, total fish biomass within the Marine Life Conservation District (MLCD) at Honolua, Maui was 111.8 ± 19.2 g/m^2 (average of 2016-2018), which was slightly greater than that at Kīpahulu, but two to five times greater than other open areas in Maui Nui (Figure 2).

For this report, resource fish[4] include fish desirable for food, commercial activity, or cultural practices that reside in the habitats and depth ranges surveyed by TNC divers. Total resource fish biomass was 65.1 ± 7.6 g/m^2 in 2019, which represented 72% of the total fish biomass. Surgeonfish accounted for the largest percentage of the resource fish biomass (~60%; Figure 3) in 2019. Other important groups included parrotfish and apex predators (~10% each), and wrasses and goat fish (~7% each).

Total resource fish biomass was considerably higher than other areas open to fishing on Maui (Minton *et al.* 2020) and comparable to the Honolua MLCD, which is closed to most fishing activity (Figure 4). Examining the ratio of resource fish to non-resource fish (R:NR) can shed light on fishing pressure because areas with high fishing pressure tend to have a lower R:NR ratio than areas with relatively lower fishing pressure (Minton *et al.* 2020), although other

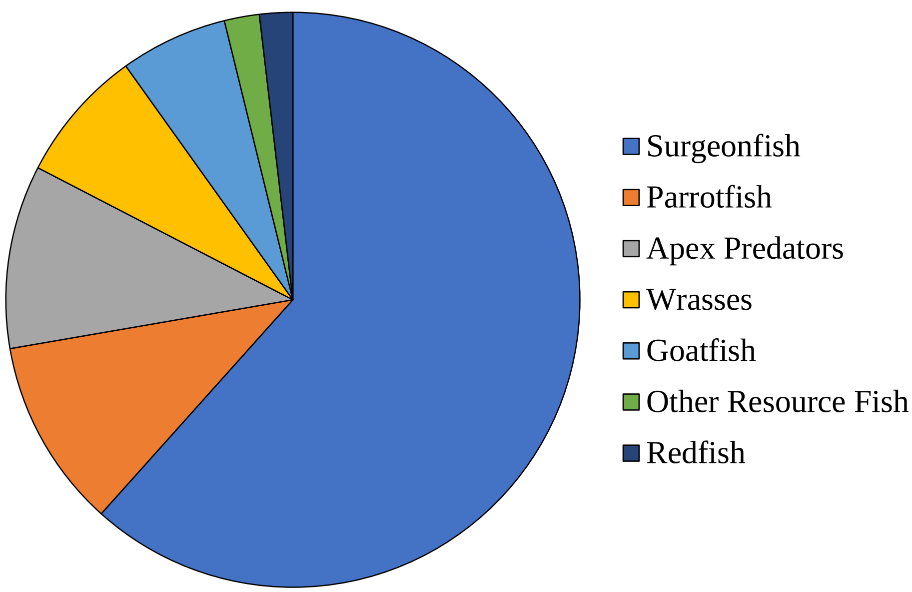

Figure 3. Resource fish composition (% of total resource fish biomass) at Kīpahulu in 2019. Reef areas inside and outside the 2010-2013 area did not differ in their composition and their pie charts are not presented here. See text and Figure 1 for more information on the 2010-2013 area.

[4] Those fish most prized by fishers. See Table 1 for a list of species that comprise the resource fish for this report.

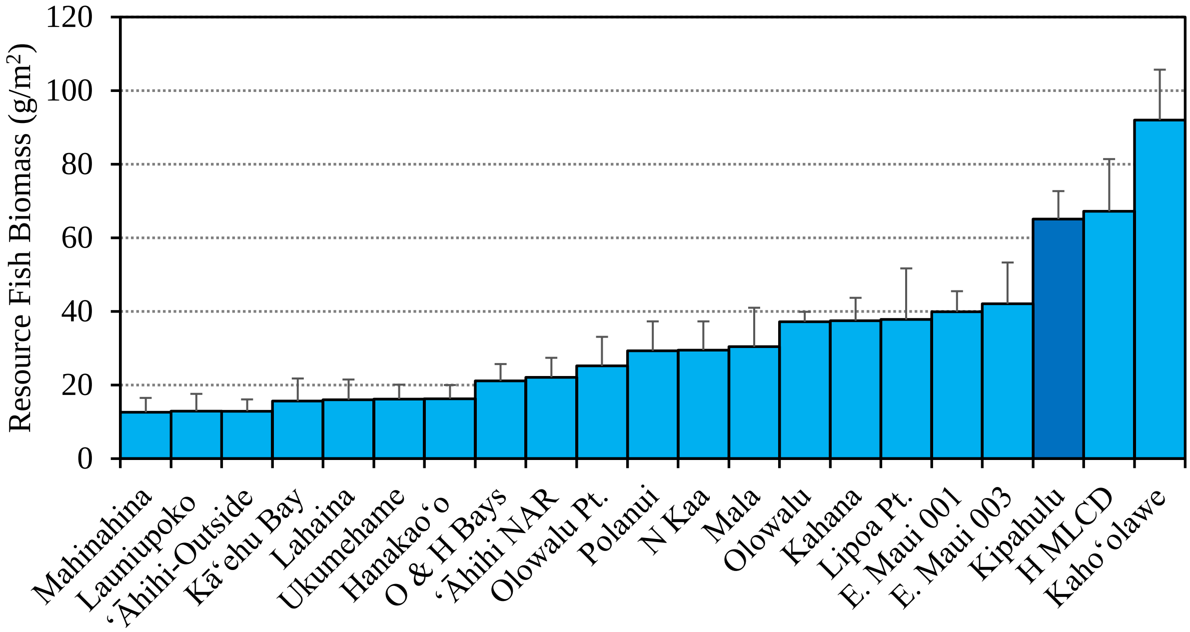

Figure 4. Resource fish biomass at Kīpahulu in 2019 (dark blue bar) and 20 Maui Nui sites. All Maui Nui sites are "open" to fishing, except the 'Āhihi-Kīna'u Natural Area Reserve ('Āhihi NAR), Honolua MLCD (H MLCD), and Kaho'olawe. West Maui data were compiled by Minton *et al.* (2020), 'Āhihi NAR and 'Āhihi-Outside by Minton *et al.* (2016a), Kaho'olawe by Minton *et al.* (2016b), and Kā'ehu Bay, E Maui 001, and East Maui 003 by TNC. Bars represent SEM. N Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays.

environmental factors can also influence this ratio. The R:NR at Kīpahulu was higher than all west Maui reef areas (Figure 5), where, with the exception of the Honolua MLCD, estimated annual fishing pressure was greater than at Kīpahulu (Figure 6).

Prime spawners are large resource fishes (>70% their maximum size) generally prized by fishers and that tend to contribute disproportionately more to the total breeding potential of the population than smaller individuals due to the prime spawners' greater egg and sperm production (*i.e.*, fecundity) and the higher survivorship of their larvae (Williams *et al.* 2008). Therefore, prime spawner biomass is a good indicator of fishing impacts (*e.g.*, prime spawner biomass often decreases as fishing pressure increases,), while representing an important component of ecological function (*i.e.*, population breeding potential).

At Kīpahulu, the prime spawner biomass in 2019 was 38.7 ± 5.3 g/m^2 in 2019, which is among the highest observed in Maui Nui in recent years (Figure 7) and in the main Hawaiian Islands over the last two decades (Minton *et al.* 2014). Prime spawner biomass in the Honolua MLCD was 22.7 ± 9.8 g/m^2, just over half that observed at Kīpahulu, and highlights the "regional" effects of fishing on closed areas discussed above and demonstrates the importance of Kīpahulu's remoteness from Maui's population center. Prime spawners were also not restricted to a few

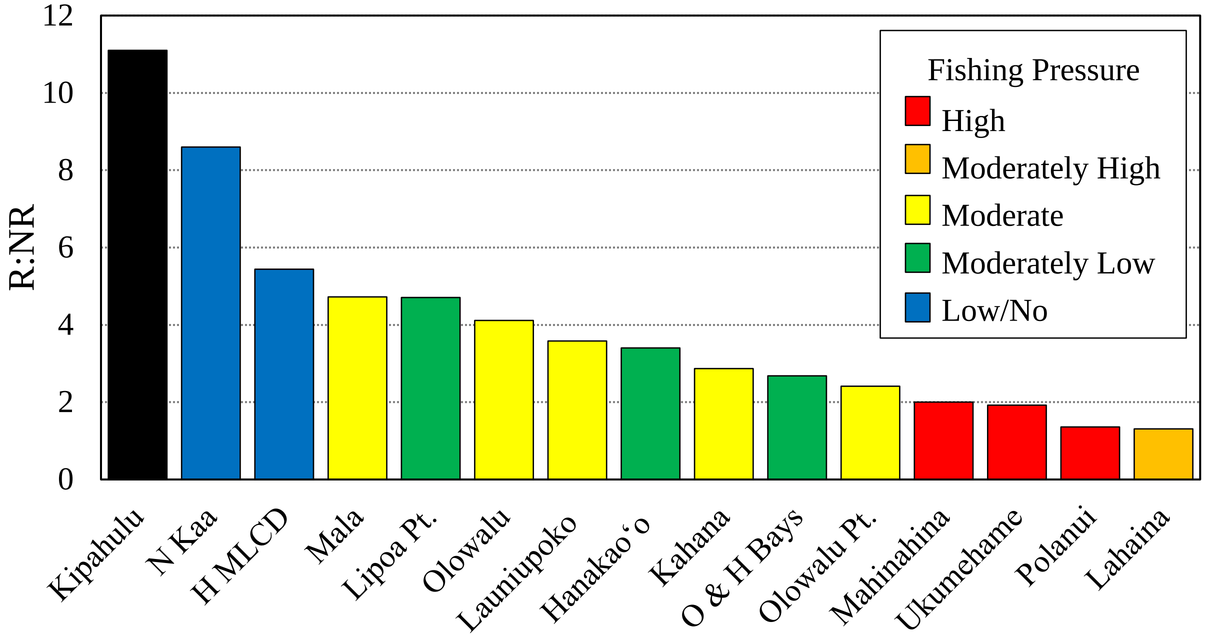

Figure 5. Ratio of mean resource fish biomass to non-resource fish biomass (R:NR) for 14 reef areas in west Maui. N Kaa=North Kaanapali; H MLCD=Honolua MLCD; O & H Bays= Oneloa and Honokaua Bays. Figure modified from Minton *et al.* (2020).

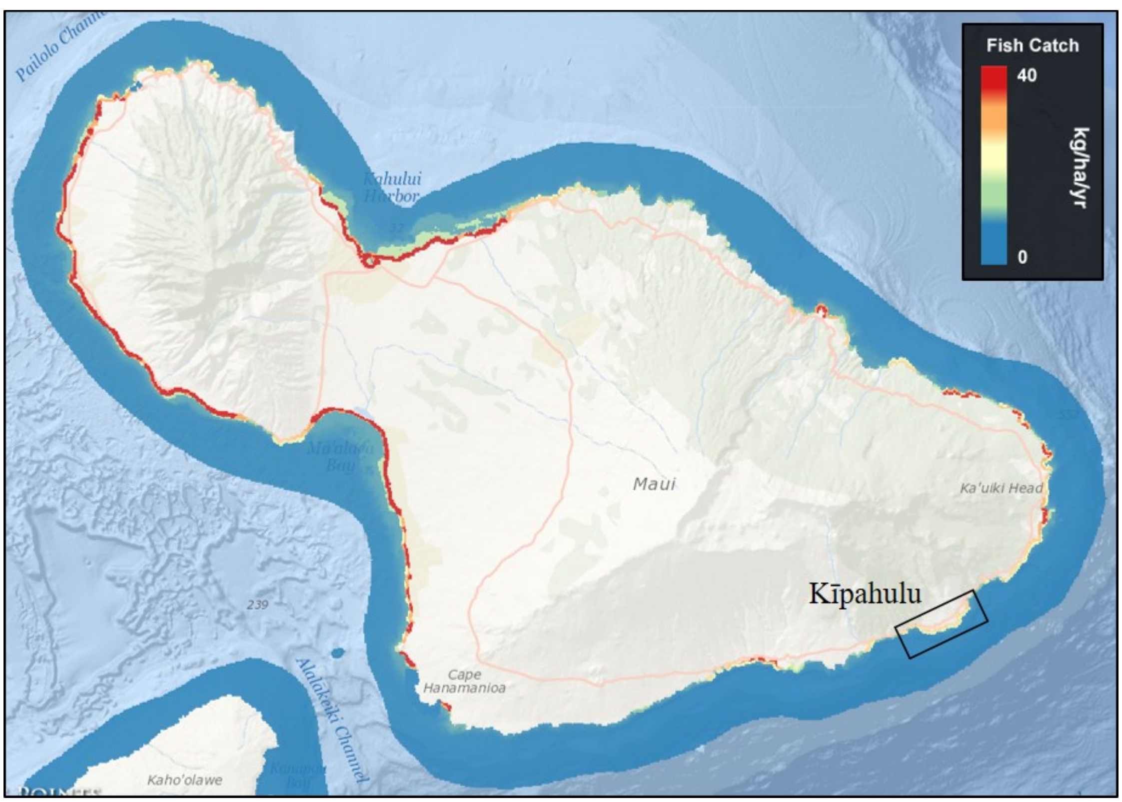

Figure 6. Estimated average annual catch for non-commercial fisheries from 2004-2013. Data and figure modified from The Ocean Tipping Points project (2016) and PacIOOS.

species; most species had prime spawners, including nearly all resource surgeonfishes, goatfishes, and parrotfishes, further suggesting limited fishing impacts at Kīpahulu and a fish assemblage that still appears to be in fairly good condition. Notably, however, of the eight apex predator species observed at Kīpahulu, only one, the green jobfish (*Aprion virescens* or *uku*), had prime spawner individuals.

These data suggest little evidence for significant local fishing impacts on Kīpahulu's reef, although it should be noted that these comparisons are made among contemporary sites, most of which are have greater fishing pressure than Kīpahulu (Figure 6), and not by comparing current with historical fish populations at Kīpahulu itself. While community members have described abundant fish populations at Kīpahulu that existed nearly a half century ago (Minton *et al.* 2016), comparable quantitative data to make within-site temporal comparisons with the 2019 survey effort at Kīpahulu were not available and likely do not exist. Likewise, a broader context is needed to fully understand fishing pressure on Maui and the other main Hawaiian Islands. Many coral reef fish species, especially large, predatory species (*e.g.*, sharks, jacks, etc.) range widely, which exposes them to fishing pressure even if their range may overlap a no fishing area. These wide-ranging species are subject to "regional" fishing pressure, which can result in lower fish biomass even in protected or remote areas. Compared to areas like the Northwestern Hawaiian Islands (Friedlander and DeMartini 1992) and other relatively remote and unfished

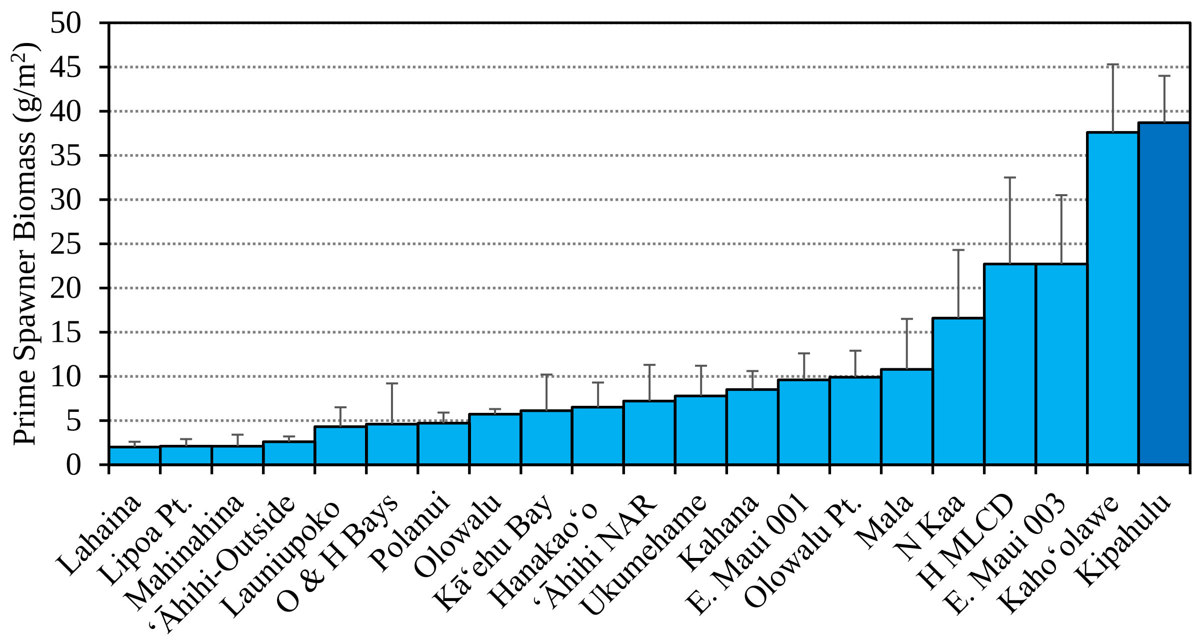

Figure 7. Prime spawner biomass at Kīpahulu in 2019 (dark blue bar) and 20 Maui Nui sites. All Maui Nui sites are "open" to fishing, except the ʻĀhihi-Kīnaʻu Natural Area Reserve (ʻĀhihi NAR), Honolua MLCD (H MLCD), and Kahoʻolawe. West Maui data were compiled by Minton *et al.* (2020), ʻĀhihi NAR and ʻĀhihi-Outside by Minton *et al.* (2016a), Kahoʻolawe by Minton *et al.* (2016b), and Kāʻehu Bay, E Maui 001, and East Maui 003 by TNC. Bars represent SEM. N Kaa=North Kaanapali; O & H Bays= Oneloa and Honokaua Bays.

reefs (Sandin *et al.* 2008), areas closed to fishing in the main Hawaiian Islands show considerable adverse effects of fishing. Within this context, however, fishery resources at Kīpahulu are still in remarkably good condition compared to other areas on Maui and throughout the main Hawaiian Islands.

Three species of invasive fish were observed at Kīpahulu: peacock grouper or *roi* (*Cephalopholis argus*), bluestriped snapper or *ta'ape* (*Lutjanus kasmira*), and blacktail snapper or *to'a* (*Lutjanus fulvus*). While not statistically significant due to high variability, invasive fish biomass tended to be greater outside the 2010-2013 area than inside (t-test; $t_{19}=1.73$; $p=0.131$), driven primarily by more bluestriped snapper at several sites outside the 2010-2013 area (Table 5). Only a single bluestripe snapper was observed inside the 2010-2013 area; in contrast nearly 400 bluestriped snapped occurred at over half the sites outside the area. Peacock grouper, a species of considerable concern among fishers, were rarely observed, occurring at only 6 of 36 sites (16%) at Kīpahulu, and with one exception, never more than a single small individual was observed by surveyors at a site. While more common than peacock groupers, blacktail snapper were also relatively uncommon at Kīpahulu in 2019, and were generally restricted to a small number of individuals at a third of the sites; however, one site outside the 2010-2013 area had a sizeable school (57 individuals) of blacktail snappers.

Table 5. Mean (±SEM) biomass (g/m^2) of invasive fish observed during the 2019 surveys on the Kīpahulu reef, Maui. The 2019 Kīpahulu survey area was comprised of reef area inside and outside the 2010-2013 area. See text and Figure 1 for more information.

Fish Family	**Kīpahulu**	**Outside**	**Inside**
Peacock grouper	0.3 ± 0.2	0.1 ± 0.1	0.5 ± 0.4
Blacktail snapper	1.6 ± 0.6	1.9 ± 0.9	1.4 ± 0.9
Bluestripe snapper	4.1 ± 2.6	8.2 ± 5.1	<0.1
Invasive Fish	6.1 ± 2.7	10.2 ± 5.2	2.0 ± 1.3

Change Over Time

Discerning a temporal trend in Kīpahulu's fish assemblage was difficult due to high annual variability and only three sampling years. In 2013, fish biomass was significantly lower than in 2010 (Minton *et al.* 2014) but appeared to recover in 2019. This pattern was consistent for total fish, resource fish, and prime spawner biomass (Figure 8; Appendix B). While drawing a clear conclusion from these data is difficult, it is highly likely that fish populations did not decline between 2010 and 2013 and then recover by 2019, and instead, the sampling effort in 2013 simply yielded biomass estimates on the low end of the biomass range present at Kīpahulu. Survey effort in 2010 and 2013 were limited and likely below optimal[5]. Given the consistent

[5] Optimal survey effort on most reefs in Hawai'i generally entails ~40 survey sites. Given logistical constraints, primarily predictable windows of weather suitable for surveys, meeting this survey effort has always been challenging at Kīpahulu.

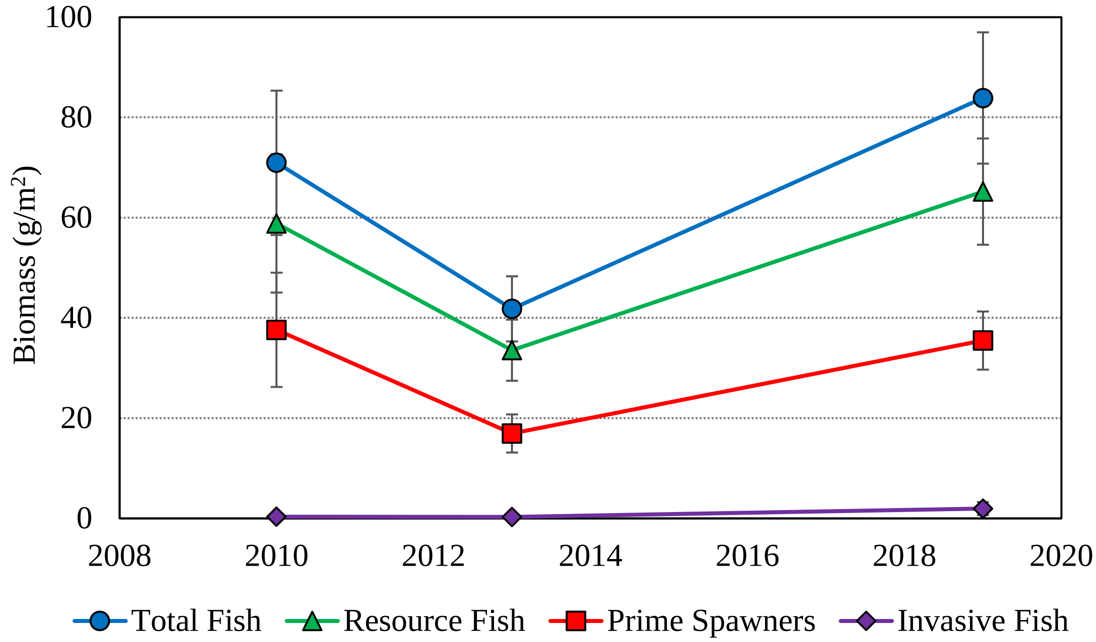

Figure 8. Change in average total fish, resource fish, prime spawner, and invasive fish biomass (±SEM) at Kīpahulu in 2010, 2013, and 2019. Biomass estimates for 2019 were derived only from sites that occurred inside the 2010-2013 area. See text and Figure 1 for more information.

survey effort between years, reasons for the low estimate are not clear, but changes in environmental conditions such as inclement weather can alter fish distributions on shallow reefs (Walsh 1983). It is also possible that the random selection of sites resulted in a "draw" of more sites with lower fish biomass than in either 2010 and 2019, and suggest that a more robust sampling effort within a sampling year, as well as more survey years, may be necessary to better capture the spatial and annual variability in Kīpahulu's fish assemblage and to identify temporal trends. This highlights the challenges associated with monitoring coral reef fish populations and the importance of multi-year assessments to identify trends and provide data to assist with management.

Species Targeted for CBSFA Management

In their CBSFA proposal, the Kīpahulu community has identified several species as primary targets for their management actions (Kīpahulu Ohana 2019). While several of these species were not the focus of TNC's 2019 Kīpahulu survey effort, useful information was collected on the following species of management interest to the community: goldring bristletooth or *kole* (*Ctenochaetus strigosus*), bluespine unicornfish or *kala* (*Naso unicornis*), parrotfish or *uhu* (family Scaridae), and goatfish (family Mullidae).

Goldring bristletooth or *kole* (*Ctenochaetus strigosus*)

Goldring bristletooth are often an abundant and conspicuous surgeonfish on Hawaiian reefs. However, relatively few were observed at Kīpahulu in 2019; a trend that has continued from earlier Kīpahulu surveys (Minton *et al.* 2014). Only two individuals were observed across the 2019 survey area, neither of which occurred within the 2010-2013 area. During the two previous survey efforts (2010 and 2013), a total of eight individuals were observed on transects, with only 10 more individuals observed during extensive "off-transect," timed-swim surveys. These timed-swim surveys covered more reef area and may be better at detecting low density and "diver wary" species. These data suggest that goldring bristletooth are relatively uncommon on Kīpahulu reefs. Given the small number of individuals observed in 2019, meaningful size distribution information could not be derived for the species.

Harvest of goldring bristletooth is unregulated in Hawaiʻi, and due to its abundance and ease of catch, it is a popular recreational and subsistence fishery species within the state. It is also the second most abundantly caught fish in the aquarium-trade fishery after yellow tang (*Zebrasoma flavescens*); however, it is unlikely that a significant amount of aquarium fishing for goldring bristletooth occurs at Kīpahulu. Unfortunately, the recreational fishing pressure on the species at Kīpahulu is unknown, and insufficient information exists to make historic quantitative estimates of the abundance of the species in the area.

Bluespine unicornfish or *kala* (*Naso unicornis*)

Average biomass for bluespine unicornfish was similar inside and outside the 2010-2013 area, averaging 4.0 ± 1.2 g/m^2, which accounted for over 9% of the surgeonfish biomass at Kīpahulu. Biomass in 2019 was similar to that observed in both 2010 and 2013. Average fish length in 2019 was 32.0 ± 1.5 cm, with individuals ranging from 6 to 56 cm (max length in Hawaiʻi is 62 cm).

Harvest of bluespine unicornfish is lightly regulated in Hawaiʻi, and it is a popular recreational and subsistence fishery species. Legal harvest size is 35.5 cm (14 in), and no bag limit exists. At Kīpahulu, bluespine unicornfish show signs consistent with harvest pressure; 76% of individuals were below the legal harvest size. However, 12% of individuals were of prime spawner size, which suggests the fishery may be in relatively good condition at Kīpahulu compared to other reefs in the state. These findings are consistent with an area experiencing relatively low fishing effort.

Parrotfish or *uhu* (family Scaridae)

Three species of parrotfish, or *uhu*, were observed at Kīpahulu in 2019, with the ember (*Scarus rubroviolaceus*) and stareye (*Calotomus carolinus*) parrotfish together accounting for most of the observed individuals (Table 6) and parrotfish biomass. Only a single bullethead parrotfish (*Chlorurus spilurus*) was observed. The bullethead parrotfish is often a common species on reefs around Hawaiʻi, and in addition to its rarity in 2019, it was entirely absent from survey sites at Kīpahulu during both 2010 and 2013. While this species is an important reef fishery species, its absence from Kīpahulu is likely not fishing related. Even in heavily fished areas, bullethead parrotfish tend to be the most common parrotfish species present. The rarity of this species at Kīpahulu suggests something other than fishing may be responsible for its absence. Interestingly, bullethead parrotfish were also rare or absent at other east Maui locations, suggesting its rarity is extended regionally to east Maui and not restricted to Kīpahulu alone. At this time, no explanation is available, but it is likely related to environmental and/or habitat factors. Two species observed in previous surveys, the palenose (*Scarus psittacus*) and spectacled (*Chlorurus perspicillatus*) parrotfish (Minton *et al.* 2014) were also not seen in 2019. While the spectacled parrotfish was uncommon in 2010 and 2013 (6 total individuals), the palenose parrotfish was the second most abundant species and occurred at numerous sites during the earlier surveys. Reasons for its absence in 2019 are unclear.

Parrotfish biomass in 2019 did not differ between reef areas inside and outside the 2010-2013 area and averaged 6.9 ± 1.4 g/m^2. Parrotfish were observed on 24 of 36 transects, indicating a wide distribution within the moku, which is consistent with previous survey efforts. During the timed swims conducted in previous years, surveyors observed an additional 89 parrotfish off transects, with ember parrotfish accounting for vast majority of individuals. These data in their entirety suggest ember parrotfish have been relatively abundant, large in size, and widespread at Kīpahulu since at least 2010. In contrast, other *uhu* species appear to be present on Kīpahulu's reefs, but in much lower abundance.

In 2019, ember parrotfish averaged 44.4 ± 1.0 cm in length, which is well above the 35.5 cm (14 in) size for legal harvest on Maui[6]. Along the transects, 95% of the observed ember parrotfish were above legally harvestable size. In contrast, stareye parrotfish averaged 13.1 ± 2.6 cm in length, and few were of harvestable size (25.4 cm/10 in)[5], although this result should be view cautiously given the relatively small number of stareye parrotfish observed during the 2019 surveys. Average length of ember parrotfish in 2010 and 2013 was 32.3 ± 1.7 cm, 12 cm shorter than that found in 2019. While the Kīpahulu surveys were not intended to assess the effects of Maui's new parrotfish regulations, this increase in mean size for ember parrotfish from 2013 to

Table 6. The number of individuals (N) observed on transects inside the 2010-2013 area, average (±SEM) size, maximum size, size at maturity, and percent of the fish observed that were larger than the size at maturity for the three parrotfish species observed at Kīpahulu in 2019. All sizes are in centimeters. Maximum size is for the species in Hawai‘i.

Parrotfish	N	Average size	Max. Size[1]	Size at Maturity[2]	Percent Mature
Ember	22	44.4 ± 1.0	71	35	95%
Stareye	7	13.1 ± 2.6	50	24	14%
Bullethead	1	-	40	17	-

[1]From Randall (2007)
[2]From DeMartini and Howard (2016)

[6] New fishing regulations specific to Maui Island were enacted in 2014, altering the legal size and establishing bag limits. Elsewhere in the Hawai‘i, legal harvest size for all parrotfish is 30.5 cm (12 inches), with no bag limit.

2019 would be consistent with that expected from the parrotfish rule change. This would assume, however, that sufficient fishing pressure exists on ember parrotfish at Kīpahulu. Evidence suggests ember parrotfish were targeted locally; two-thirds of individuals observed in 2010-2013 were under the legal harvest size at that time (30.5 cm). While prime spawners were rarely observed in 2019 (1 individual), numerous individuals just below prime spawner size were noted. These data suggest the ember parrotfish population at Kīpahulu is exploited, but is still in relatively good condition, especially for a reef open to fishing in Hawaiʻi, and may have benefited from the recent changes in regulations governing parrotfish harvest.

Goatfish (family Mullidae)

Six species of goatfish were observed at Kīpahulu in 2019 (Table 7), with the manybar or *moano* (*Parupeneus multifasciatus*) accounting for two-thirds of all individuals, and over a third of the total goatfish biomass. Average goatfish biomass was 3.9 ± 1.3 g/m^2, which was slightly higher than in 2013 (1.8 ± 0.6 g/m^2), but considerably lower than 2010 (13.7 ± 3.1 g/m^2), and goatfish were observed on 28 of 36 transect in 2019, indicating a widespread distribution on Kīpahulu's reefs.

The State of Hawaiʻi has established minimum legal harvest sizes for three of the goatfish species observed at Kīpahulu. Manybar goatfish can be legally harvested at 17.8 cm (7 inches). In 2019, approximately 47% of the observed individuals were above harvestable size. Likewise, yellowstripe goatfish (*Mulloidichthys flavolineatus*) or *weke* can be legally harvested at 17.8 cm, but a bag limit of 50 fish exists for yellowstripe goatfish <17.8 cm (known locally as *ʻoama*), so a fishery exists for all sizes of this species. While only 10 yellowstripe goatfish were observed on transect lines in 2019, this species was absent on transects in 2010-2013, but commonly

Table 7. The number of individuals (N) observed on transects inside the 2010-2013 area, average (±SEM) size, maximum size, size at maturity, and percent of the fish observed that were larger than the size at maturity for the six goatfish species observed at Kīpahulu in 2019. All sizes are in centimeters. Maximum size is for the species in Hawaiʻi.

Goatfish	N	Average size	Max. Size[1]	Size at Maturity	Percent Mature
Manybar	73	15.7 ± 0.8	30	F: 15.2[2] M: 14.5	~65%
Yellowstripe	10	25.2 ± 1.6	40	F:19.9[3] M: ?	>50%
Yellowfin	10	23.8 ± 1.1	38	?	?
Island	8	23.8 ± 1.2	40.6	?	?
Sidespot	4	17.0 ± 5.9	33	?	?
Whitesaddle	3	29.0 ± 0.7	51	23.8	-

[1]From Randall (2007)
[2]From Longenecker and Langston (2008)
[3]From Cole (2009)

observed on timed-swims. Given that timed swims were not conducted in 2019, the status of this species at Kīpahulu is unclear. Whitesaddle goatfish (*Parupeneus porphyreus*) or *kūmū* are a particularly prized species and can be harvested at 25.4 cm (10 inches) in Hawaiʻi. This species was rarely sighted in 2019 (3 individuals), but this is similar to earlier surveys when only four whitesaddle individuals were observed on transects in 2010-2013 (Minton *et al.* 2014). All three individuals observed in 2019 were slightly above legal harvest size (between 28-30 cm). These data provide supporting evidence of a robust goatfish assemblage at Kīpahulu (especially compared to other open areas in the main Hawaiian Islands), but one that may be showing early indications of fishing-related impacts.

Management Recommendations

The results of the 2019 survey effort at Kīpahulu do not change the management recommendations made previously (Minton *et al.* 2014). The reefs at Kīpahulu have among the most abundant fish populations of any open site within the main Hawaiian Islands, and their abundance is on par with, and in many cases exceeds, areas already under additional fishery regulations on Maui, including areas entirely closed to fishing. Given the high annual variability across the three survey years (2010, 2013, and 2019), it is difficult to determine if a trend in the condition of reef fish populations is present at Kīpahulu. Additionally, based on the limited available data, it appears that the lower reef fish biomass observed in 2013 compared to both 2010 and 2019 was likely not representative of the "true" fish biomass in the area, and likely resulted from a relatively small sampling effort in a spatially and temporally variable assemblage. Sampling effort in 2019 was sufficient to estimate average values with good precision. As such the values obtained in 2019 (which are similar to 2010) likely represent the best available estimates of Kīpahulu's fish assemblage. To gain a clearer understanding of the coral reef fish assemblage at Kīpahulu, additional survey years would be required.

The region's abundant reef fish is likely due to its small human population, relative isolation from Maui's main population centers, and rough ocean conditions that are present much of the year that limit safe access. This assessment suggests Kīpahulu's fish populations have not been as impacted by fishing and other human-related stressors as most other areas in Hawaiʻi. Fishing at Kīpahulu appears to be limited (Figure 6), and at its current level may be sustainable. However, this conclusion must be taken with caution because the 2019 survey was not designed to assess the stability of fisheries at Kīpahulu, but to provide snap-shot assessments of the abundance, distribution, and size of fish across the Kīpahulu moku.

Unlike at the state level where quantitative information has documented significant declines through time in important fishery species, similar time series information is not readily available at Kīpahulu, yet observations of community members indicate that fisheries at Kīpahulu have likely declined considerably over the past half century. Local fishers have described abundant fishery resources present in Kīpahulu 40-50 years ago, noting that fish would "come up to smell your spear" and "papio would come when you snap under water." Additionally, "every tide pool had *moi ʻili* every year" and juvenile *manini* (*pua*) were abundant, and *kūmū* were very abundant and occurred in large schools. Unfortunately it's not possible to quantify these historic levels and make direct comparisons with our survey data. All we can conclude is that fishery abundance and biomass have likely declined over the past 40-50 years, suggesting there may be room for improvement.

Reasons for the decline in fisheries are not entirely clear, but fishing, both at the local and regional scale, has likely played some role. Local fishers have noted that dynamite and bleach fishing occurred at Kīpahulu in the 1950s and 1960s. While fishers suspect that invasive fish such as peacock grouper and various snapper species may have impacted native fish populations, invasive fish species were relatively rare at Kīpahulu during our surveys, with the exception of the bluestriped snapper, which was locally abundant. Bluestriped snapper may compete with some native goatfish for space on the reef, making these goatfish more susceptible to predation and fishers (Schumacher and Parrish 2005), but this snapper has not been found to adversely affect other native fishes (Friedlander *et al.* 2002). Given that Kīpahulu has fish stocks comparable to closed areas in the state, local fishing pressure is likely not the primary cause of historic fishery declines. However, regional fishing (*i.e.*, Maui-wide) may be partially responsible for the current fish biomass at Kīpahulu, especially for mobile species with large ranges (*e.g.*, jacks, etc.). During this same time period, the watershed above Kīpahulu' reef has likely improved as sugar cane and other large-scale agriculture have been replaced with small-scale agriculture, and lands have been shifted to be under the conservation management of the National Park Service. This suggests that the impacts of landbased sources of pollution on the fish assemblage may have declined in the last half-century, although feral cattle and pig abundances on non-National Park Service lands are believed to be high, which would contribute to upland erosion and sediment flushing onto the nearshore reefs. Many sites visited in 2019 had substantial amounts of sediment entrained in algal turf on the benthos. East Maui receives >200 cm/year of rainfall, and heavy rainfall the evening of Oct 2, 2019 caused several large sediment plumes throughout the survey areas, causing the survey team to cancel the final planned day of diving.

Undoubtedly, Kīpahulu had greater fishery resources in the past than are currently present, and community members have expressed interest in seeing their marine resources return to those levels. Whether that is possible is unknown. Kīpahulu already has fishing resources comparable to many closed areas in the state, and it's unclear how much impact fishing elsewhere on Maui has had on Kīpahulu's reef. While there are indications for some species that fishing pressure may be having an effect on populations (discussed above), these impacts were relatively modest and enacting additional fishery management may not result in a significant increase in fish biomass, yet it may be important for maintaining fish populations, especially if access to the Kīpahulu reef, and thus fishing pressure, were to increase in the future. If fishing access increases without additional management in place, Kīpahulu could experience rapid and significant declines in fish biomass, similar to other more populated and open areas on Maui.

The benthic community at Kīpahulu has always likely been a low coral-cover, boulder reef community. The Kīpahulu coastline is exposed, and frequently experiences rough sea conditions that are not conducive to extensive or diverse coral growth. The two most common coral species, lobe and cauliflower corals, are tolerant of high energy environments (CRAMP 2008), and bear resemblance to other windward and exposed reefs in Hawaiʻi. The reefs at Kīpahulu are dominated by low-growing turf algae growing on basalt pavement and boulders. Caves and other large relief topography are relatively common along the coastline and likely provide considerable habitat heterogeneity capable of supporting large fish populations. The composition and condition of the benthic assemblage suggests it may be experiencing some impacts typical of poor water quality, specifically, high algal turf cover and evidence of sediment-related stress on some coral colonies. The limited extent of these survey efforts (both in number of sites and years in which surveys were conducted) makes it difficult to identify temporal trends and assess the magnitude of these potential stressors or to conclusively identify the possible upland sources (*e.g.*, feral ungulates, cattle, invasive plant species), but additional upland management of sediment and nutrient sources may be warranted.

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Appendix A. Kīpahulu Site Data: 2010-2019

Site Name	Survey Date	Latitude	Longitude	Rugosity	Depth(ft)	Depth(m)	2010-2013 area
2010-KIP-002	9/22/2010	20.661008	-156.039287	1.12	48.5	14.8	Yes
2010-KIP-005	9/23/2010	20.65165	-156.04627	1.3	36.4	11.1	Yes
2010-KIP-016	9/22/2010	20.657403	-156.043722	1.26	35.4	10.8	Yes
2010-KIP-017	9/23/2010	20.657792	-156.045983		21.6	6.6	Yes
2010-KIP-020	9/22/2010	20.659556	-156.042077	1.4	26.9	8.2	Yes
2010-KIP-022	9/22/2010	20.652558	-156.045813	1.27	33.1	10.1	Yes
2010-KIP-025	9/22/2010	20.648887	-156.05231	1.38	23.9	7.3	Yes
2010-KIP-026	9/23/2010	20.654463	-156.04512		32.5	9.9	Yes
2010-KIP-028	9/23/2010	20.662615	-156.039502	1.4	16.4	5	Yes
2010-KIP-029	9/23/2010	20.650477	-156.052009	1.67	24.6	7.5	Yes
2010-KIP-030	9/23/2010	20.658116	-156.042469	1.35	29.8	9.1	Yes
2010-KIP-033	9/22/2010	20.650653	-156.047967	1.45	26.6	8.1	Yes
2010-KIP-037	9/22/2010	20.64995	-156.049794	1.11	29.5	9	Yes
2010-KIP-040	9/23/2010	20.661095	-156.040725	1.45	14.1	4.3	Yes
2013-KIP-041	7/17/2013	20.65831	-156.043494	1.35	24.9	7.6	Yes
2013-KIP-042	7/15/2013	20.657254	-156.045164	1.25	30.8	9.4	Yes
2013-KIP-043	7/15/2013	20.653617	-156.045172	1.35	39	11.9	Yes
2013-KIP-045	7/17/2013	20.654383	-156.044709	1.3	37.1	11.3	Yes
2013-KIP-046	7/15/2013	20.660342	-156.041961	1.25	16.1	4.9	Yes
2013-KIP-048	7/18/2013	20.661001	-156.038021	1.4	21.6	6.6	Yes
2013-KIP-049	7/18/2013	20.659804	-156.040159	1.2	47.6	14.5	Yes
2013-KIP-050	7/15/2013	20.649276	-156.051005	1.2	47.9	14.6	Yes
2013-KIP-055	7/17/2013	20.650901	-156.051713	1.1	21	6.4	Yes
2013-KIP-056	7/15/2013	20.649524	-156.048026	1.3	43	13.1	Yes
2013-KIP-057	7/17/2013	20.656739	-156.043393	1.15	48.5	14.8	Yes
2013-KIP-059	7/16/2013	20.668282	-156.037584	1.25	37.4	11.4	No

Site Name	Survey Date	Latitude	Longitude	Rugosity	Depth(ft)	Depth(m)	2010-2013 area
2013-KIP-062	7/16/2013	20.649648	-156.049398	1.3	35.4	10.8	Yes
2013-KIP-064	7/17/2013	20.655189	-156.045523	1.4	17.1	5.2	Yes
2013-KIP-071	7/16/2013	20.662681	-156.037411	1.2	37.4	11.4	Yes
2013-KIP-072	7/17/2013	20.649985	-156.052434	1.3	29.5	9	Yes
2013-KIP-073	7/18/2013	20.661736	-156.036232	1.25	34.1	10.4	Yes
2013-KIP-074	7/16/2013	20.661634	-156.038914	1.5	28.5	8.7	Yes
2013-KIP-078	7/16/2013	20.651138	-156.047316	1.6	40	12.2	Yes
2013-KIP-079	7/18/2013	20.658553	-156.041119	1.33	49.9	15.2	Yes
2013-KIP-080	7/16/2013	20.65909	-156.042824	1.45	21	6.4	Yes
2019-KIP-005	10/2/2019	20.650473	-156.050861	1.025	28	8.5	Yes
2019-KIP-009	9/30/2019	20.647258	-156.061702	1.285	22	6.7	No
2019-KIP-010	10/1/2019	20.64907	-156.049665	1.33	50	15.2	Yes
2019-KIP-014	10/2/2019	20.651256	-156.046545	1.55	39	11.9	Yes
2019-KIP-015	9/30/2019	20.646709	-156.06843	1.33	13	4	No
2019-KIP-021	9/30/2019	20.661049	-156.038131	1.355	21	6.4	Yes
2019-KIP-025	9/30/2019	20.651523	-156.045872	1.2	45	13.7	Yes
2019-KIP-030	10/2/2019	20.645627	-156.085538	1.445	31	9.4	No
2019-KIP-031	9/30/2019	20.657746	-156.042707	1.48	23	7	Yes
2019-KIP-032	10/1/2019	20.657352	-156.04673	1.485	12	3.7	Yes
2019-KIP-034	10/1/2019	20.647155	-156.063339	1.4	12	3.7	No
2019-KIP-039	9/30/2019	20.65	-156.052985	1.255	25	7.6	Yes
2019-KIP-041	10/2/2019	20.650674	-156.052395	1.3	20	6.1	Yes
2019-KIP-043	10/2/2019	20.64584	-156.06735	1.715	35	10.7	No
2019-KIP-050	9/30/2019	20.64976	-156.048703	1.385	41	12.5	Yes
2019-KIP-051	9/30/2019	20.647741	-156.082477	1.68	21	6.4	No
2019-KIP-052	10/1/2019	20.662179	-156.038213	1.21	30	9.1	Yes
2019-KIP-053	9/30/2019	20.647445	-156.072866	1.57	23	7	No
2019-KIP-054	10/1/2019	20.645601	-156.065286	1.295	27	8.2	No

Site Name	Survey Date	Latitude	Longitude	Rugosity	Depth(ft)	Depth(m)	2010-2013 area
2019-KIP-055	10/1/2019	20.665569	-156.039683	1.235	18	5.5	No
2019-KIP-058	10/1/2019	20.649631	-156.07512	1.325	14	4.3	No
2019-KIP-061	10/2/2019	20.650785	-156.077287	1.35	6	1.8	No
2019-KIP-069	9/30/2019	20.662219	-156.036688	1.45	42	12.8	Yes
2019-KIP-071	10/2/2019	20.656071	-156.04547	1.125	34	10.4	Yes
2019-KIP-076	10/1/2019	20.647064	-156.071541	1.13	30	9.1	No
2019-KIP-078	10/1/2019	20.650621	-156.046113	1.53	49	14.9	Yes
2019-KIP-079	10/2/2019	20.661235	-156.036878	1.32	30	9.1	Yes
2019-KIP-080	10/2/2019	20.645986	-156.06029	1.235	40	12.2	No
2019-KIP-084	9/30/2019	20.659459	-156.042158	1.4	13	4	Yes
2019-KIP-085	10/2/2019	20.646499	-156.055222	1.135	35	10.7	No
2019-KIP-086	10/1/2019	20.650036	-156.054824	1.49	13	4	No
2019-KIP-087	9/30/2019	20.648685	-156.054802	1.115	29	8.8	No
2019-KIP-093	10/2/2019	20.644946	-156.063497	1.645	41	12.5	No
2019-KIP-096	10/1/2019	20.647983	-156.074024	1.395	26	7.9	No
2019-KIP-098	10/2/2019	20.657215	-156.044098	1.39	41	12.5	Yes
2019-KIP-099	10/1/2019	20.656083	-156.046301	1.275	14	4.3	Yes

Appendix B. Supplemental Tables

Table B.1. Mean (±SEM) biomass (g/m^2) of fish by family at Kīpahulu in 2010, 2013, and 2019. Biomass estimates for 2019 were derived only from sites that occurred inside the 2010-2013 area. See text and Figure 1 for more information. Data from 2010 and 2013 are from Minton *et al.* (2014).

Fish Family	**2019**	**2010**	**2013**
Surgeonfish (Acanthuridae)	42.4 ± 8.3	35.1 ± 11.6	23.3 ± 5.6
Snappers (Lutjanidae)	6.1 ± 4.4	0.7 ± 0.4	2.7 ± 1.8
Parrotfish (Scaridae)	6.8 ± 1.7	9.0 ± 2.8	3.4 ± 1.6
Wrasses (Labridae)	9.2 ± 1.5	7.2 ± 1.2	4.9 ± 0.5
Goatfish (Mullidae)	2.9 ± 1.0	11 ± 2.6	1.6 ± 0.6
Triggerfish (Balistidae)	3.7 ± 1.0	2.2 ± 0.4	2.0 ± 0.4
Butterflyfish (Chaetodontidae)	4.1 ± 3.0	1.5 ± 0.3	0.7 ± 0.1
Damselfish (Pomacentridae)	1.4 ± 0.5	1.0 ± 0.3	0.4 ± 0.1
Chub (Kyphosidae)	0.5 ± 0.4	0	0.2 ± 0.1
Jacks (Carangidae)	1.0 ± 0.5	0.4 ± 0.3	0.3 ± 0.3
Squirrelfish (Holocentridae)	1.8 ± 1.3	<0.1	<0.1
Emperors (Lethrinidae)	1.7 ± 1.4	1.4 ± 1.1	0
Moorish Idol (Zanclidae)	0.9 ± 0.5	0.3 ± 0.2	0.3 ± 0.2
Hawkfish (Cirrhitidae)	0.4 ± 0.1	1.1 ± 0.2	0.6 ± 0.1
Groupers (Serranidae)	0.5 ± 0.4	0	0.1 ± 0.1
Pufferfish (Tetraodontidae)	0.3 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
Filefish (Monacanthidae)	0.1 ± 0.1	0.1 ± 0.1	0.9 ± 0.5
Angelfish (Pomacanthidae)	<0.1	<0.1	<0.1
Trumpetfish (Aulostomidae)	0	0	<0.1
Boxfish (Ostraciidae)	0	0	<0.1
Blennies (Blenniidae)	<0.1	<0.1	<0.1
Porcupinefish (Diodontidae)	0	0	0.1 ± 0.1
Scorpionfish (Scorpaenidae)	0	<0.1	0
Lizardfish (Synodontidae)	0	0	0
Eels (Muraenidae)‡	+	+	+
Unidentified Fish‡	+		
Total Fish Biomass	83.9 ± 13.1	70.9 ± 14.4	41.8 ± 6.5

‡Counted, but biomass could not be estimated. A "+" indicates individuals were observed during the survey round. See methods for more discussion.

Table B.2. Mean (±SEM) biomass (g/m^2) of resource fish by resource fish group at Kīpahulu in 2010, 2013, and 2019. Biomass estimates for 2019 were derived only from sites that occurred inside the 2010-2013 area. See text and Figure 1 for more information. Data from 2010 and 2013 are from Minton *et al.* (2014).

Resource Group	2019	2010	2013
Surgeonfish	39.4 ± 8.1	33.5 ± 11.5	22.8 ± 5.6
Parrotfish	6.8 ± 1.7	9.0 ± 2.8	3.4 ± 1.6
Apex Predators	5.7 ± 4.4	0.7 ± 0.4	2.7 ± 1.8
Wrasses	7.3 ± 1.6	3.2 ± 0.9	3.0 ± 0.6
Goatfish	2.9 ± 1.0	11.0 ± 2.6	1.6 ± 0.6
Other Resource Fish	1.7 ± 1.4	1.4 ± 1.1	0
Redfish	1.5 ± 1.2	0	0
Total Resource Fish	65.2 ± 10.6	58.9 ± 13.8	33.6 ± 6.1

Table B.3. Mean (±SEM) biomass (g/m^2) of invasive fish at Kīpahulu in 2010, 2013, and 2019. Cover estimates for 2019 were derived only from sites that occurred inside the 2010-2013 area. See text and Figure 1 for more information. Data from 2010 and 2013 are from Minton *et al.* (2014).

Invasive Species	2019	2010	2013
Peacock grouper	0.5 ± 0.4	0	0.1 ± 0.1
Blacktail snapper	1.4 ± 0.9	0.2 ± 0.2	0.1 ± 0.1
Blustripe snapper	<0.1	0.1 ± 0.1	0.1 ± 0.2
Invasive Fish	2.0 ± 1.3	0.3 ± 0.2	0.3 ± 0.2

Appendix C. Glossary of Scientific Terms

Abundance: The relative representation of a species in a particular ecosystem. It is usually measured as the number of individuals found per sample.

Assemblage: All of the various species of a particular type or group that exist in a particular habitat (*e.g.*, all fish, all coral). A species assemblage is a subset of all of the species within an ecological community, *e.g.*, the fish assemblage is part of the coral reef community.

Belt Transect: A sampling unit used in biology to investigate the distribution of organisms in relation to a certain area. It provides the surveyor with a boundary to record the number of individuals for all the species found within a given measurement of that particular line. Belt transects are functionally similar to quadrats but tend to be larger

Benthic Organism: An animal or plant that resides primarily on the bottom, whether attached (*e.g.*, coral, algae), or unattached (*e.g.*, snail, crabs).

Biomass: The mass of living biological organisms in a given area or ecosystem at a given time. Usually expressed as a mass or weight per unit area (*e.g.*, tons/acres or g/m^2).

Quadrat (Photo-quadrat): A square used in ecology to isolate a sample, usually with a relatively small area (*e.g.*, 0.25 m^2 or 1 m^2). A quadrat is suitable for sampling sessile or slow-moving animals. A photo-quadrat is a picture taken of a quadrat.

Rugosity: A measure of small-scale variations in the height of the reef. As a measure of complexity, rugosity is presumed to be an indicator of the amount of habitat available for colonization by benthic organisms (those attached to the seafloor), and shelter and foraging area for mobile organisms.

Turbidity: A measure of the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye.