



# Kalaupapa National Historical Park (KALA) Marine Fish Monitoring Program Annual Status Report for 2009

## *Pacific Island Network*

Natural Resource Data Series NPS/PACN/NRDS—2012/310



**ON THE COVER**

Bluespine unicornfish (*Naso unicornis*) at Kalaupapa National Historical Park, Molokaʻi, Hawaiʻi.  
Photograph by: Courtesy of Kalaupapa National Historical Park, Molokaʻi, Hawaiʻi.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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## Executive Summary

Kalaupapa National Historical Park (KALA) is located on the north shore of the island of Moloka'i and encompasses a wide variety of habitats from submerged marine resources to lowland coastal, mesic, and rainforest habitats as well as three offshore islands. The marine boundary of the park extends a quarter mile offshore around the park shoreline and encompasses approximately 2,000 acres.

The objective of the marine fish monitoring protocol is to annually determine the density and size of reef fishes at sites randomly selected on hard substrata in an isobath between the 10 and 20 m depths (Brown et al. 2011). From 2006-2009, a total of 30 transects (sites) were sampled each year. A split panel sampling design was used with 15 transects randomly established at the onset as fixed or permanent transects. These fixed transects were surveyed in 2006 and will be continually surveyed on an annual basis. The remaining 15 temporary transects were randomly selected each year and surveyed only in that year. Data collection consisted of a visual count and size estimation of all fish within 25 x 5 m underwater belt transects. Scientific divers were used to conduct this non-destructive technique and focused on the diurnal or day-active fish species that were highly visible due to their typically bright coloration and generally large size. This report includes the status of the fish populations at all 30 transects in 2009 and trends at the fifteen fixed transects from 2006-2009.

In 2009:

- Fish species richness ranged from 14 to 40 species per transect (125 m<sup>2</sup>). Patches of high species richness were found in three locations: on the western side of the peninsula, near the northern tip of the peninsula, and near the eastern boundary of the park.
- The density of fish at all transects ranged from 272 to 3,176 fish/km<sup>2</sup> x 1,000. The highest fish density values were concentrated near the northern tip of the peninsula, while consistently low values were found near the eastern and western boundaries of the park.
- At most transects, fish biomass ranged between approximately 20 and 460 metric tons/km<sup>2</sup>. However, two transects fell well outside this range: at Fixed Transect 6, located on the northwestern coast of the peninsula, the biomass was only 5.4 metric tons/km<sup>2</sup>, while at Fixed Transect 8, located at the northern tip of the peninsula, the biomass was 1,167.5 metric tons/km<sup>2</sup>.
- High (up to 3.13) and low (down to 1.05) fish diversity (H') values were distributed fairly evenly throughout the park.
- Secondary consumers accounted for approximately 77% of the fish density observed during surveys in 2009, while apex predators accounted for just 1%, with primary consumers making up the remaining 22%. In contrast, the relative biomass of secondary consumers was 43%, compared to 13% for apex predators and 44% for primary consumers.
- In terms of density, the secondary consumer *Chromis vanderbilti* was by far the most abundant species found at Kalaupapa in 2009. It was more than five times as abundant as the next most common taxon in the park, the primary consumer *Kyphosus* spp. Seven of the top ten most abundant species by density were secondary consumers, while three were primary consumers.

- The bulk of the biomass was accounted for by *Kyphosus* spp. and the introduced snapper *Lutjanus kasmira* (a secondary consumer). The top ten most abundant species by biomass were composed of four primary consumers, three secondary consumers, and three apex predators.

Trends at the 15 fixed transects surveyed annually from 2006-2009 showed that:

- Mean fish species richness remained relatively stable (approximately 24 species per transect).
- Mean fish density has declined since monitoring was initiated. In 2006, mean fish density was  $1,905 \pm 446$  SE fish/km<sup>2</sup> x 1,000, while in 2009 that number had fallen to  $1,121 \pm 230$  SE fish/km<sup>2</sup> x 1,000.
- Mean fish biomass remained relatively stable (approximately 166 metric tons/km<sup>2</sup>).
- Mean fish diversity (H') hovered around 2 between 2006-2008, but jumped to 2.28 in 2009.

## **Acknowledgments**

We would like to thank Randall Watanuki, other KALA staff, and all the volunteers at Kalaupapa National Historical Park for their continuing logistical support in collecting the data for this report. Financial assistance was provided by the Pacific Island Network Inventory and Monitoring Program. We could not have done the work without this support.

## **List of Terms and Acronyms**

KALA: Kalaupapa National Historical Park

PACN: Pacific Island Network

Trophic groups: groups defined by nutritional habits and requirements



## Introduction

Because of their importance ecologically, culturally and economically, it is critical that Pacific Island Network (PACN) parks have scientifically rigorous data on the current health and long-term trends of the marine fish communities within their boundaries. In most Pacific parks, coral reefs form an important component of the ecosystem, and have been compared to tropical rainforests in terms of their high species diversity and complexity of interactions (Connell 1978, Birkeland 1997). Within coral reefs, marine fish are one of the most visible resources and certainly the most exploited.

Kalaupapa National Historical Park (KALA) in the PACN is located in Hawai'i on the north shore of the island of Moloka'i, and encompasses a wide variety of habitats from submerged marine resources to lowland coastal, mesic, and rainforest habitats as well as three offshore islands (Figure 1). The park preserves and interprets the Kalaupapa settlement and Hansen's disease patients, but public visitation is restricted. The marine boundary of the park extends a quarter mile offshore around the park shoreline and encompasses approximately 2,000 acres. Significant marine resources include the presence of threatened (green sea turtle) and endangered (monk seal, humpback whale) species, high wave energy coral reef communities, and relatively healthy marine intertidal and fish resources. The most common species of hermatypic corals occur at KALA, but prevailing oceanographic conditions prevent coral reef formation. The intertidal areas consist of exposed basalt benches, low and high cliffs, basalt boulder and cobble beaches, sand beaches, and numerous tide pools that provide habitat for juvenile fish species. Upland development (including sedimentation and other runoff-associated issues) and overfishing (including from commercial fishing vessels) are significant anthropogenic factors affecting fish communities at KALA.

The initial source of information on fish assemblages at KALA is from Beets et al. (2010) who surveyed the reefs from 2004 to 2005. Their data on species richness, numerical density, biomass, and diversity was the first known study to document fish habitat utilization patterns within the park boundaries. Recently, Coles et al. (2008) surveyed the offshore islands in and around the park for unique fish species, numerical density levels, biomass, and diversity. Reef Environmental Education Foundation (REEF; [www.reef.org](http://www.reef.org)) also has two sites on the north coast of Moloka'i that provide species checklist information in similar habitats.

The methodology to monitor coral reef fish has been developed over the past 25 years, resulting in several commonly used survey techniques (e.g., Bohnsack and Bannerot 1986, Rogers et al. 1994, English et al. 1997, Samoilys 1997, Sweatman et al. 1998, Atlantic and Gulf Rapid Reef Assessment 2000, Hill and Wilkinson 2004). The technique adopted for PACN consists of a visual count and size estimation of fish by scientific divers along underwater 25 m x 5 m belt transects (Brown et al. 2011). This non-destructive technique focuses on one major component of the coral reef fish community—the diurnal or day-active fish species that are highly visible due to their typically bright coloration and generally large size. These species are the most heavily targeted by local fishers. While the small, cryptic or nocturnal species contribute to biodiversity and may be of ecological or management importance, the additional effort and time required to sample nocturnal and cryptic fish is not usually feasible with available resources. The visual estimate of fish size is an important component of these surveys for several reasons. First,

lengths allow a conversion from fish numbers to biomass by using established length-weight relationships. Second, lengths are often a useful indicator of fishing pressure or population dynamics, e.g., a trend of decreasing sizes may indicate overfishing, or recruitment year classes. Third, there is a strong positive correlation between fish size and fecundity (reproductive potential) which, along with recruitment success, is important in assessing ecological services provided by park fish stocks.

The purpose of this report was to document the status of the marine fish assemblage at KALA in 2009 and examine changes from 2006 to 2009. First, the status of the entire assemblage in 2009 was analyzed for species richness, density, biomass and diversity using spatial distribution maps. Second, the trophic composition of the entire assemblage in 2009 was examined for both density and biomass. Third, the top ten species in 2009 in terms of density and biomass were listed to examine specific components of the assemblage. Finally, trends in the entire assemblage from 2006-2009 were plotted for species richness, density, biomass, and diversity.

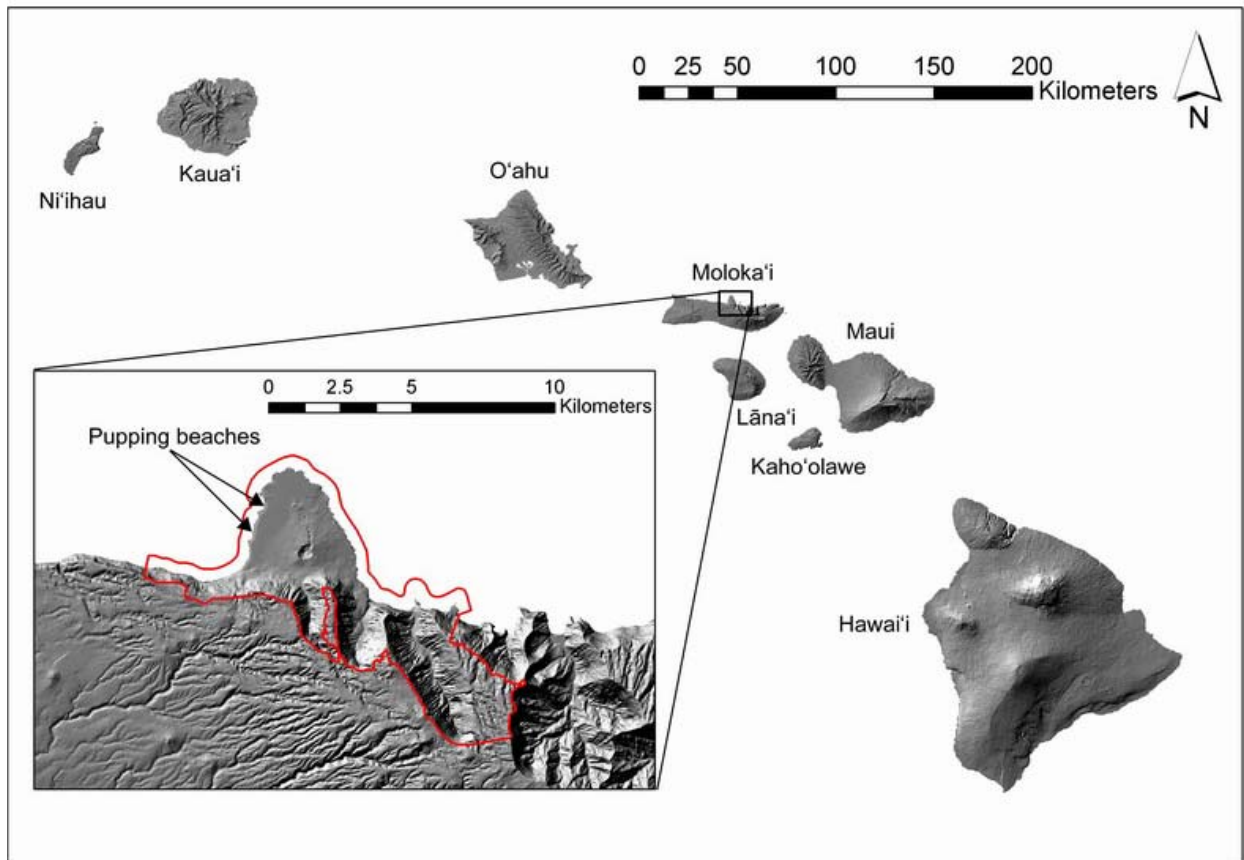


**Figure 1.** Map of the main Hawaiian Islands showing Kalaupapa National Historical Park with the park boundary delineated as a red line in the inset.

## Methods

### Sampling Locations

A split panel design was used with 30 belt transects (25 m long x 5 m wide) sampled annually between 2006 and 2009 (Brown et al. 2011). All transects were randomly selected using ArcMap<sup>®</sup> within the KALA sampling frame on hard bottom substrate in the depth zone between the 10-20 m isobaths (Figure 2). Fifteen fixed (permanent) transects were randomly selected at the onset of the monitoring program in 2006 and marked with stainless steel pins for relocation purposes. These sites were sampled every subsequent year. The remaining 15 temporary transects were randomly selected each year of monitoring and sampled only once. Transect locations were located in the field using a GPS unit.

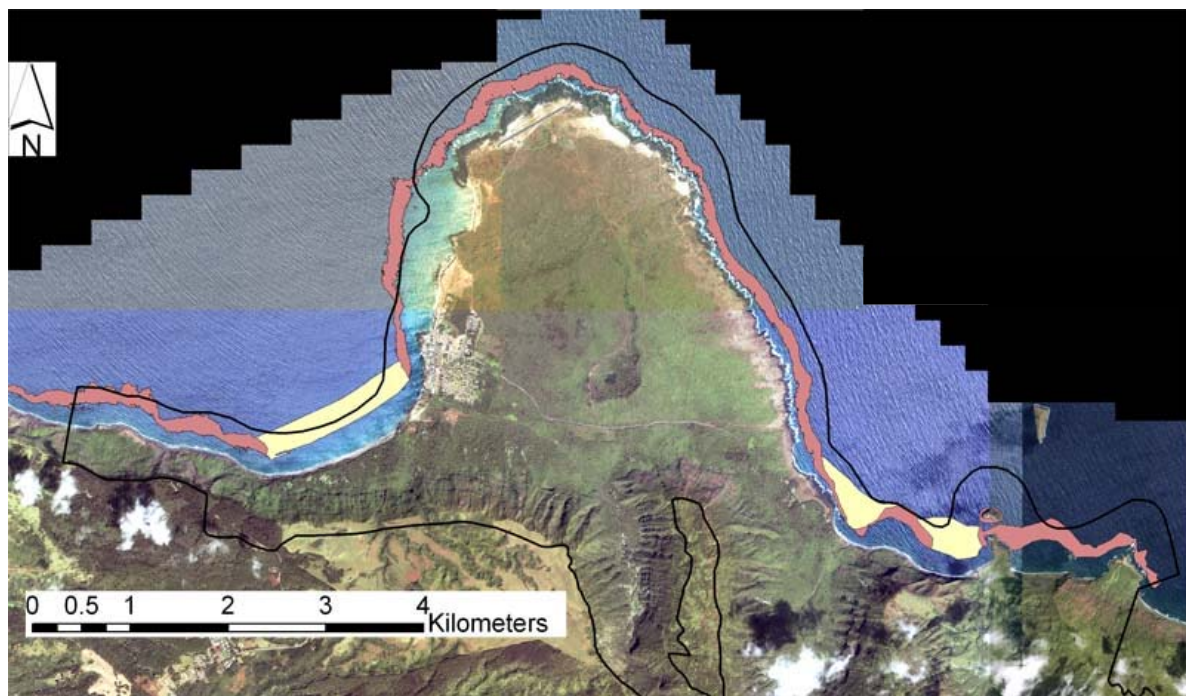


**Figure 2.** Light red polygons show sampling frame between 10 m and 20 m depth on hard bottom substrate at Kalaupapa National Historical Park. Sand habitat is shown by yellow polygons.

### Survey Methods

Surveys occurred during the summer months from July through August. At each site, using SCUBA, the fish observer deployed a transect line along a constant depth contour which was typically parallel to shore. Locations, bearings, and depths of all 2009 transects are in Table 1. The observer counted and estimated the length (to the nearest centimeter) of all fish encountered along the distance of this transect. For this report, total length is used instead of standard length.

### Data Analyses

Fish species richness for each transect was calculated by summing the number of different species observed per transect area (125 m<sup>2</sup>).

Fish density at each transect was the total number of fish observed within each transect area of 125 m<sup>2</sup>. This initial value was extrapolated to the number of fish per square kilometer (no./km<sup>2</sup>) for display purposes and for comparison with other studies. To reduce the number of significant digits, fish densities represented in figures and tables are divided by 1,000, and need to be multiplied by 1,000 to get the actual density [(no./km<sup>2</sup>) x 1,000].

Length estimates of fishes were converted to biomass using the following length-mass relationship derived for each species: Mass = a\*(Standard Length)<sup>b</sup> where a and b are species-specific constants for the allometric growth equation, standard length (SL) is in millimeters, and mass is in grams (Kulbicki et al. 1993, Friedlander et al. 2003). Total length was converted to standard length using conversion factors obtained from FishBase (www.fishbase.org). Length-mass fitting parameters were available for 150 species commonly observed on visual fish transects in Hawai'i from the Hawai'i Cooperative Fishery Research Unit (Friedlander et al., 1997). This was supplemented with information from other published and web-based sources. In the cases where length-mass information did not exist for a given species, the parameters from similar bodied congeners are used. Biomass estimates for each transect were converted to metric tons per square kilometer (mt/km<sup>2</sup>) to facilitate comparisons with other studies worldwide.

The Shannon index (H') was used to calculate species diversity within each transect using the following formula:

$$H' = - \sum_{i=1}^S (p_i \ln p_i)$$

where S is the total number of species and  $p_i$  is the frequency of the  $i$ th species in that transect.

To determine the trophic composition of the fish assemblage, each species was classified as a primary consumer, secondary consumer, or apex predator. Information on fish trophic group classifications was obtained from Friedlander et al. (1997), Fishbase, and other web-based sources.

# Results

## Metadata

A total of fifteen fixed and fifteen temporary transects were surveyed at Kalaupapa National Historical Park in 2009 (Table 1). The survey time period spanned 24 days from July 13, 2009 to August 5, 2009 with 7 days of actual field time to conduct the surveys.

## Status of Fish Assemblage Characteristics

Fish species richness ranged from 14 to 40 species per transect (125 m<sup>2</sup>; Figure 3). Patches of high species richness were found in three locations: on the western side of the peninsula, near the northern tip of the peninsula, and near the eastern boundary of the park.

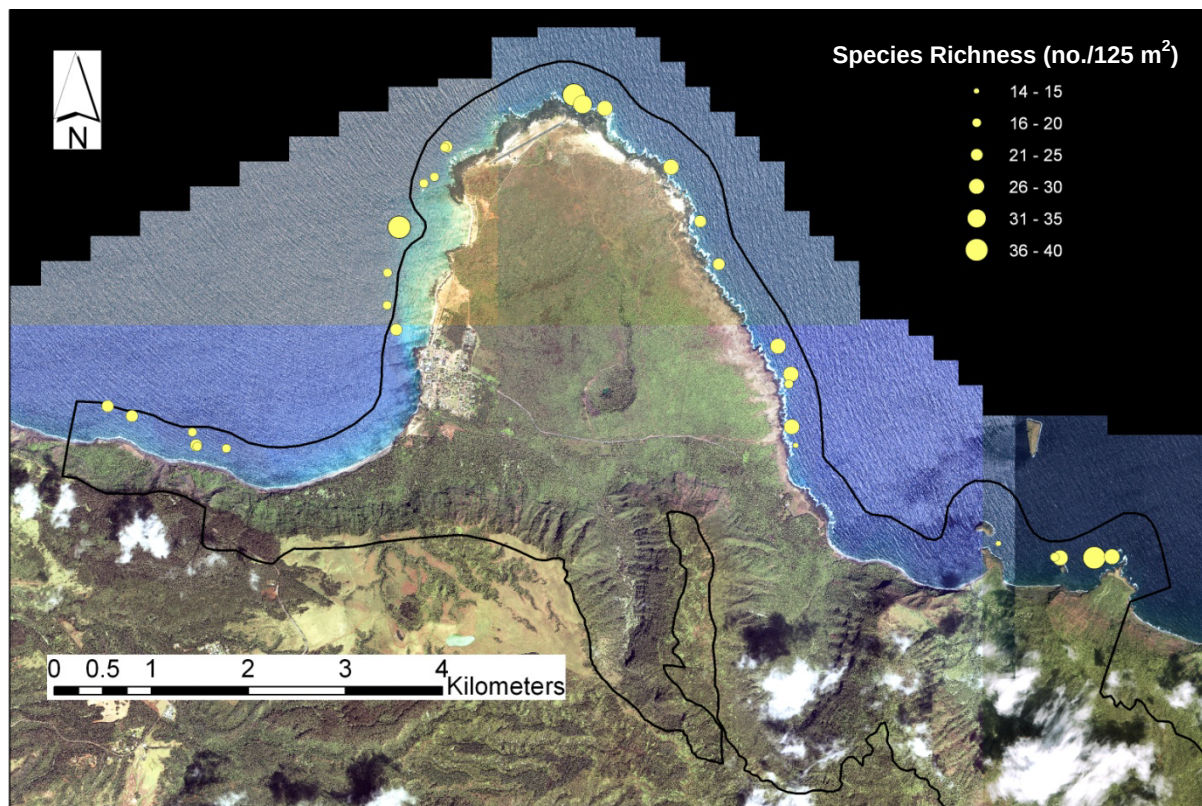


**Figure 3.** Fish species richness (no./125 m<sup>2</sup>) at Kalaupapa National Historical Park in 2009.

The density of fish at all transects ranged from 272 to 3,176 fish/km<sup>2</sup> x 1,000 (Figure 4). The highest fish density values were concentrated near the northern tip of the peninsula, while consistently low values were found near the eastern and western boundaries of the park.

At most transects, fish biomass ranged between approximately 21 and 460 metric tons/km<sup>2</sup> (Figure 5). However, two transects fell well outside this range: at Fixed Transect 6, located on the northwestern coast of the peninsula, the biomass was only 5.4 metric tons/km<sup>2</sup>, while at Fixed Transect 8, located at the northern tip of the peninsula, the biomass was 1,167.5 metric tons/km<sup>2</sup>.

**Table 1.** Metadata for Kalaupapa National Historical Park in 2009.

| Year | Transect Type | Transect | UTM Zone | Datum | X (UTM) | Y (UTM) | Survey Date | Bearing (°) | Depth (m) | Chain_length (m) | Tape_length (m) | Rugosity |
|------|---------------|----------|----------|-------|---------|---------|-------------|-------------|-----------|------------------|-----------------|----------|
| 2009 | Fixed         | 1        | 4N       | NAD83 | 706010  | 2344139 | 7/13/2009   | 90.00       | 17.50     | 39.48            | 25.21           | 1.57     |
| 2009 | Fixed         | 2        | 4N       | NAD83 | 706258  | 2344036 | 7/13/2009   | 120.00      | 12.90     | 37.79            | 25.13           | 1.50     |
| 2009 | Fixed         | 3        | 4N       | NAD83 | 708983  | 2344924 | 8/3/2009    | 0.00        | 14.20     | 41.72            | 25.47           | 1.64     |
| 2009 | Fixed         | 4        | 4N       | NAD83 | 708894  | 2345511 | 7/17/2009   | 30.00       | 18.50     | 40.23            | 25.21           | 1.60     |
| 2009 | Fixed         | 5        | 4N       | NAD83 | 709266  | 2346429 | 7/13/2009   | 90.00       | 11.20     | 38.88            | 25.79           | 1.51     |
| 2009 | Fixed         | 6        | 4N       | NAD83 | 709377  | 2346496 | 8/5/2009    | 30.00       | 12.70     | 31.92            | 25.02           | 1.28     |
| 2009 | Fixed         | 7        | 4N       | NAD83 | 709481  | 2346801 | 7/17/2009   | 60.00       | 20.90     | 57.92            | 26.40           | 2.19     |
| 2009 | Fixed         | 8        | 4N       | NAD83 | 710816  | 2347337 | 7/15/2009   | 90.00       | 15.00     | 51.81            | 25.37           | 2.04     |
| 2009 | Fixed         | 9        | 4N       | NAD83 | 711136  | 2347201 | 7/15/2009   | 120.00      | 15.90     | 40.73            | 25.10           | 1.62     |
| 2009 | Fixed         | 10       | 4N       | NAD83 | 712308  | 2345598 | 7/16/2009   | 150.00      | 16.30     | 39.49            | 25.45           | 1.55     |
| 2009 | Fixed         | 11       | 4N       | NAD83 | 712922  | 2344752 | 8/5/2009    | 150.00      | 15.30     | 47.88            | 25.15           | 1.90     |
| 2009 | Fixed         | 12       | 4N       | NAD83 | 713052  | 2344465 | 7/16/2009   | 180.00      | 17.30     | 41.98            | 25.35           | 1.66     |
| 2009 | Fixed         | 13       | 4N       | NAD83 | 713059  | 2343922 | 7/16/2009   | 150.00      | 13.60     | 37.75            | 24.76           | 1.52     |
| 2009 | Fixed         | 14       | 4N       | NAD83 | 715830  | 2342575 | 8/5/2009    | 210.00      | 14.30     | 37.62            | 25.92           | 1.45     |
| 2009 | Fixed         | 15       | 4N       | NAD83 | 716364  | 2342586 | 7/14/2009   | 270.00      | 13.70     | 41.08            | 25.10           | 1.64     |
| 2009 | Temporary     | 1        | 4N       | NAD83 | 706883  | 2343870 | 7/13/2009   | 90.00       | 18.00     | 43.28            | 25.00           | 1.73     |
| 2009 | Temporary     | 2        | 4N       | NAD83 | 706919  | 2343735 | 7/13/2009   | 120.00      | 12.20     | 44.80            | 25.00           | 1.79     |
| 2009 | Temporary     | 3        | 4N       | NAD83 | 706933  | 2343722 | 8/3/2009    | 90.00       | 12.00     | 41.73            | 25.00           | 1.67     |
| 2009 | Temporary     | 4        | 4N       | NAD83 | 707233  | 2343701 | 8/3/2009    | 90.00       | 20.20     | 35.98            | 25.00           | 1.44     |
| 2009 | Temporary     | 5        | 4N       | NAD83 | 708890  | 2345174 | 7/17/2009   | 150.00      | 18.10     | 44.61            | 25.00           | 1.78     |
| 2009 | Temporary     | 6        | 4N       | NAD83 | 709013  | 2345977 | 7/17/2009   | 210.00      | 15.00     | 48.57            | 25.00           | 1.94     |
| 2009 | Temporary     | 7        | 4N       | NAD83 | 709500  | 2346806 | 8/5/2009    | 60.00       | 21.40     | 55.03            | 25.00           | 2.20     |
| 2009 | Temporary     | 8        | 4N       | NAD83 | 710903  | 2347243 | 7/15/2009   | 320.00      | 12.90     | 29.56            | 25.00           | 1.18     |
| 2009 | Temporary     | 9        | 4N       | NAD83 | 711816  | 2346599 | 8/5/2009    | 150.00      | 12.80     | 47.48            | 25.00           | 1.90     |
| 2009 | Temporary     | 10       | 4N       | NAD83 | 712116  | 2346040 | 7/16/2009   | 150.00      | 13.10     | 37.15            | 25.00           | 1.49     |
| 2009 | Temporary     | 11       | 4N       | NAD83 | 713028  | 2344364 | 7/16/2009   | 330.00      | 13.20     | 37.86            | 25.00           | 1.51     |
| 2009 | Temporary     | 12       | 4N       | NAD83 | 713102  | 2343730 | 7/14/2009   | 330.00      | 11.60     | 34.35            | 25.00           | 1.37     |
| 2009 | Temporary     | 13       | 4N       | NAD83 | 715193  | 2342722 | 7/14/2009   | 240.00      | 19.30     | 34.35            | 25.00           | 1.37     |
| 2009 | Temporary     | 14       | 4N       | NAD83 | 715769  | 2342583 | 7/14/2009   | 330.00      | 11.60     | 36.03            | 25.00           | 1.44     |
| 2009 | Temporary     | 15       | 4N       | NAD83 | 716181  | 2342574 | 7/14/2009   | 260.00      | 20.50     | 44.89            | 25.00           | 1.80     |

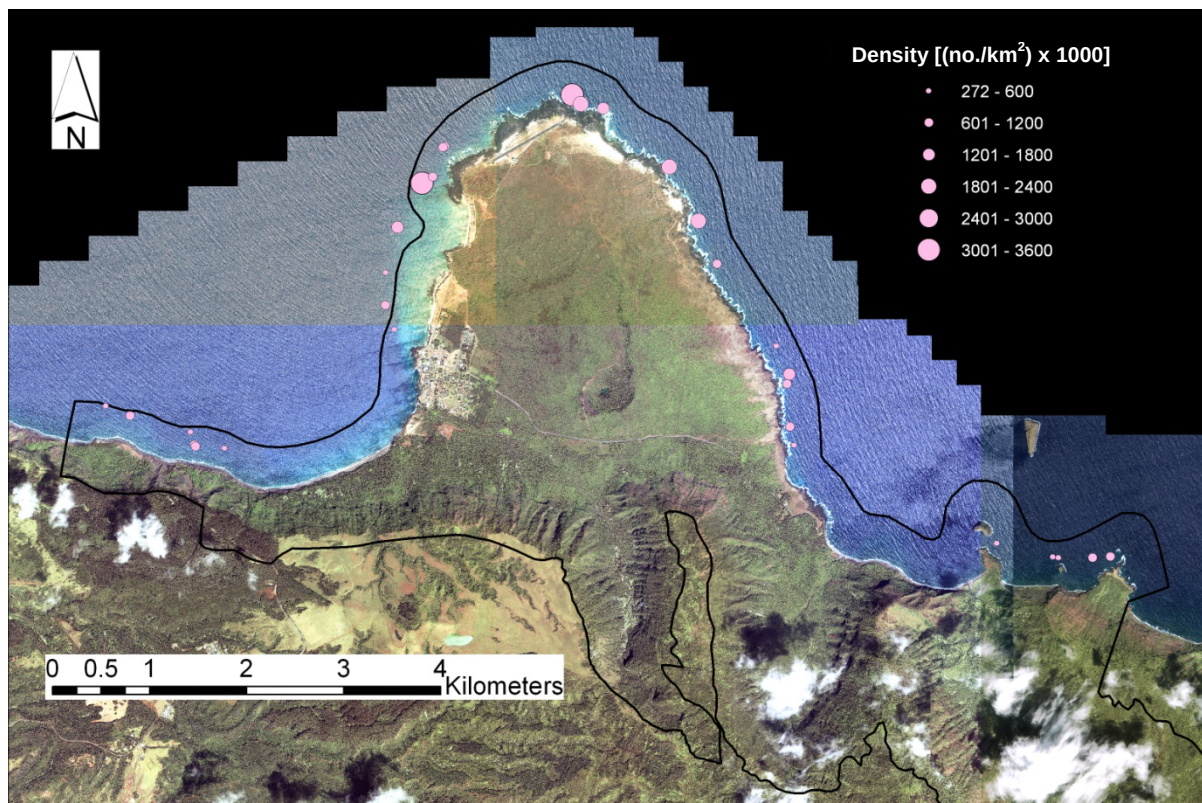


**Figure 4.** Fish density [(no./km<sup>2</sup>) x 1000] at Kalaupapa National Historical Park in 2009.

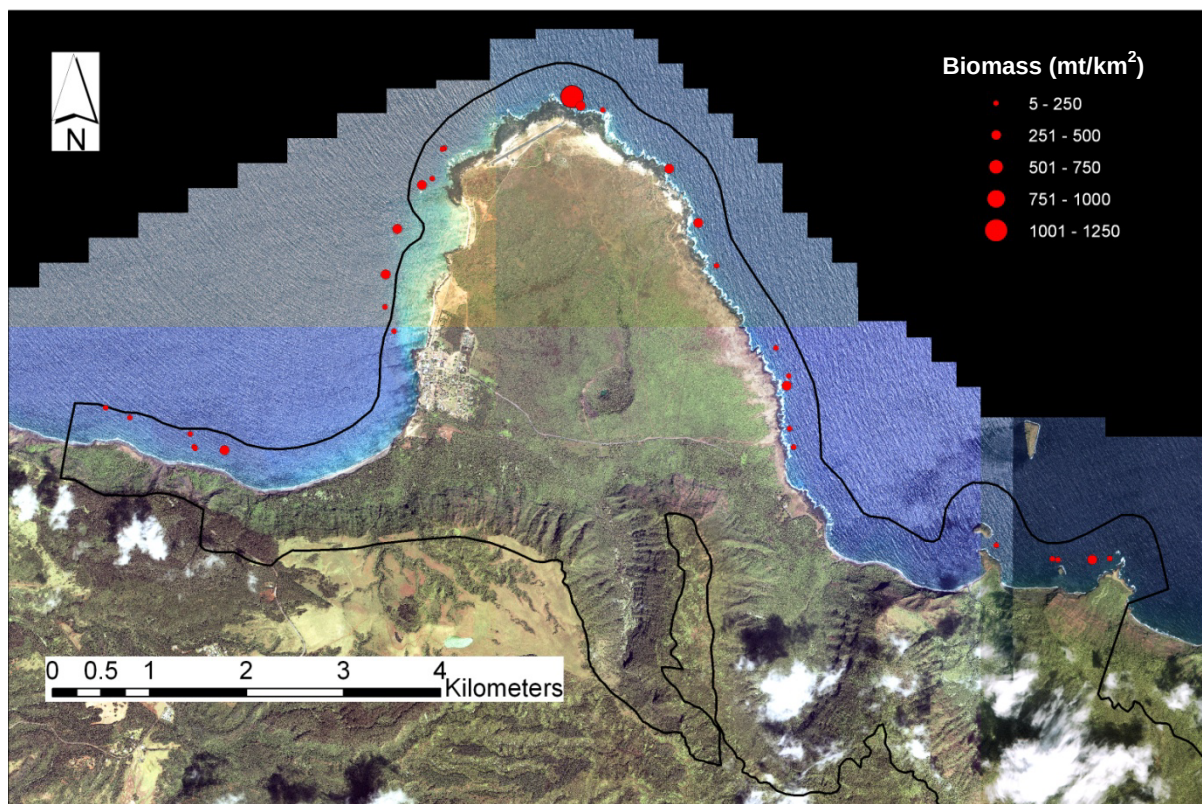


**Figure 5.** Fish biomass (mt/km<sup>2</sup>) at Kalaupapa National Historical Park in 2009.

High (up to 3.13) and low (down to 1.05) fish diversity ( $H'$ ) values were distributed fairly evenly throughout the park (Figure 6).

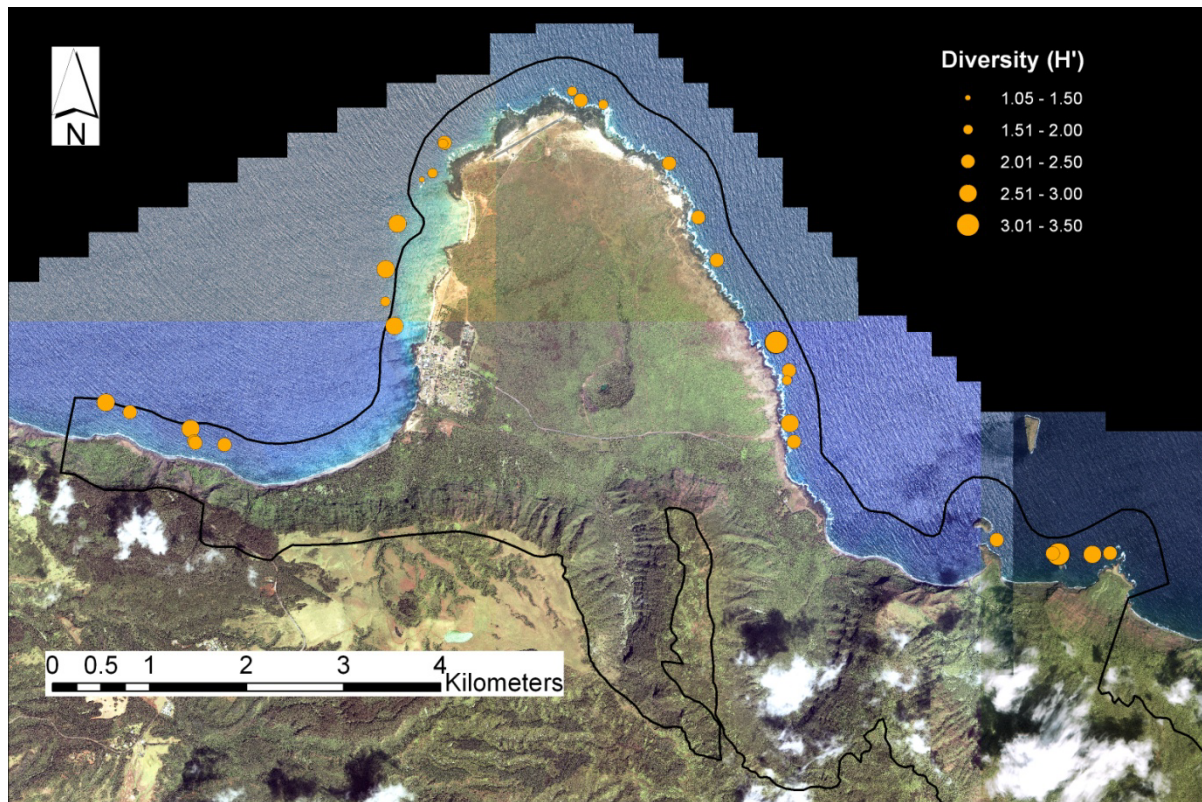


**Figure 6.** Fish diversity ( $H'$ ) at Kalaupapa National Historical Park in 2009.

### **Trophic Composition of the Fish Assemblage**

Secondary consumers accounted for approximately 77% of the fish density observed during surveys in 2009, while apex predators accounted for just 1%, with primary consumers making up the remaining 22% (Figure 7). In contrast, the relative biomass of secondary consumers was 43%, compared to 13% for apex predators and 44% for primary consumers (Figure 8).

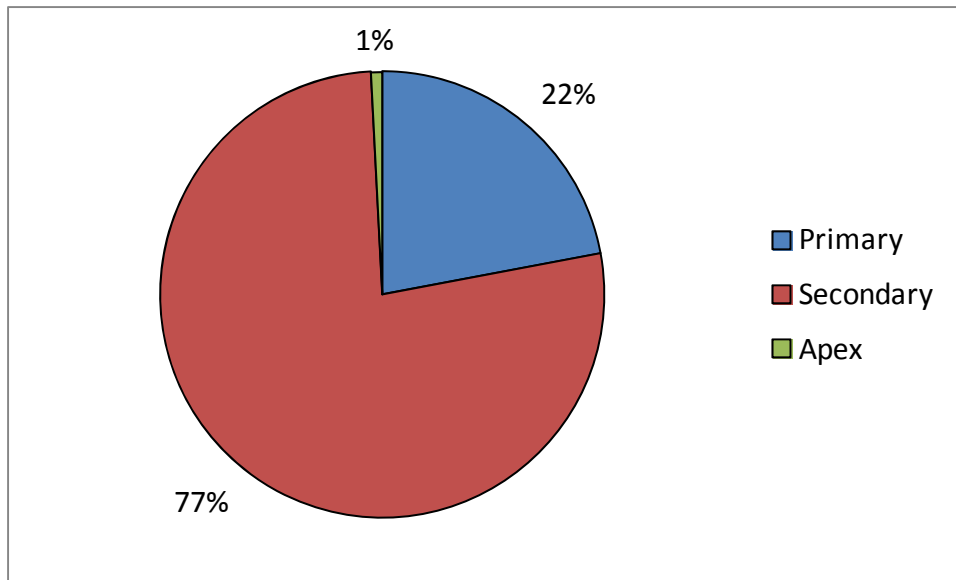


**Figure 7.** Relative density of fish consumer groups at Kalaupapa National Historical Park in 2009.

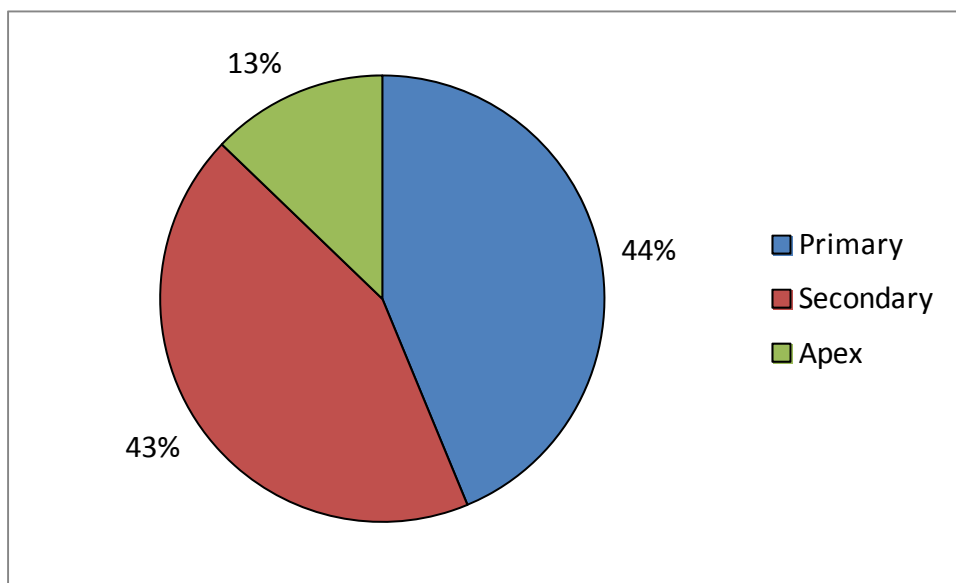


**Figure 8.** Relative biomass of fish consumer groups at Kalaupapa National Historical Park in 2009.

### Top Ten Fish Species

In terms of density, the secondary consumer *Chromis vanderbilti* was by far the most abundant species found at Kalaupapa in 2009 with  $10,800 \pm 102 \text{ SE/km}^2 \times 1,000$  documented (Table 2). It was more than five times as abundant as the next most common taxon in the park, the primary consumer *Kyphosus* spp. The bulk of the biomass, however, was accounted for by *Kyphosus* spp. ( $1,243.1 \pm 17.0 \text{ SE mt/km}^2$ ) and the introduced snapper *Lutjanus kasmira* ( $1,006.9 \pm 45.1 \text{ mt/km}^2$ ; Table 3). Seven of the top ten most abundant species by density were secondary consumers, while three were primary consumers (Table 2). In comparison, the top ten most abundant species by biomass were composed of four primary consumers, three secondary consumers, and three apex predators (Table 3).

**Table 2.** Top ten fish species by density [(no./km<sup>2</sup>) x 1000] at Kalaupapa National Historical Park in 2009. Common names are from Randall (1996).

| Species                          | Common Name           | Hawaiian Name   | Consumer Group | Density [(no./km <sup>2</sup> ) x 1000] |
|----------------------------------|-----------------------|-----------------|----------------|-----------------------------------------|
| <i>Chromis vanderbilti</i>       | Blackfin Chromis      | unknown         | Secondary      | 10800                                   |
| <i>Kyphosus</i> spp.             | Rudderfish            | nenu            | Primary        | 1984                                    |
| <i>Thalassoma duperrey</i>       | Saddle Wrasse         | hinālea lauwiki | Secondary      | 1560                                    |
| <i>Chromis ovalis</i>            | Oval Chromis          | unknown         | Secondary      | 1208                                    |
| <i>Paracirrhites arcatus</i>     | Arc-eye Hawkfish      | piliko'a        | Secondary      | 1176                                    |
| <i>Lutjanus kasmira</i>          | Bluestripe Snapper    | ta'ape          | Secondary      | 1144                                    |
| <i>Acanthurus leucopareius</i>   | Whitebar Surgeonfish  | māikoiko        | Primary        | 1120                                    |
| <i>Acanthurus nigrofusus</i>     | Brown Surgeonfish     | mā'i'i'i        | Primary        | 1096                                    |
| <i>Chaetodon lunula</i>          | Raccoon Butterflyfish | kikākapu        | Secondary      | 1024                                    |
| <i>Parupeneus multifasciatus</i> | Manybar Goatfish      | moano           | Secondary      | 872                                     |

**Table 3.** Top ten fish species by biomass (mt/km<sup>2</sup>) at Kalaupapa National Historical Park in 2009. Common names are from Randall (1996).

| Species                        | Common Name             | Hawaiian Name | Consumer Group | Biomass (mt/km <sup>2</sup> ) |
|--------------------------------|-------------------------|---------------|----------------|-------------------------------|
| <i>Kyphosus</i> spp.           | Rudderfish              | nenu          | Primary        | 1243.06                       |
| <i>Lutjanus kasmira</i>        | Bluestripe Snapper      | ta'ape        | Secondary      | 1006.89                       |
| <i>Bodianus bilunulatus</i>    | Hawaiian Hogfish        | 'a'awa        | Secondary      | 476.87                        |
| <i>Naso lituratus</i>          | Orangespine Unicornfish | umaumalei     | Primary        | 312.87                        |
| <i>Seriola dumerili</i>        | Greater Amberjack       | kāhala        | Apex           | 251.83                        |
| <i>Caranx ignobilis</i>        | Giant Trevally          | ulua aukea    | Apex           | 242.43                        |
| <i>Acanthurus leucopareius</i> | Whitebar Surgeonfish    | māikoiko      | Primary        | 238.65                        |
| <i>Naso unicornis</i>          | Bluespine Unicornfish   | kala          | Primary        | 165.16                        |
| <i>Ctenochaetus strigosus</i>  | Goldring Surgeonfish    | kole          | Secondary      | 137.14                        |
| <i>Caranx melampygus</i>       | Bluefin Trevally        | 'ōmilu        | Apex           | 123.70                        |

### Trends of Fish Assemblage Characteristics

At the 15 fixed transects surveyed annually, mean fish species richness ( $24.5 \pm 0.2$  SE; Figure 9) remained relatively stable from 2006 to 2009. Mean fish density, on the other hand, has declined since monitoring was initiated (Figure 10). In 2006, mean fish density was  $1,905 \pm 446$  SE fish/km<sup>2</sup> x 1,000, while in 2009 that number had fallen to  $1121 \pm 230$  SE fish/km<sup>2</sup> x 1,000. Mean fish biomass ( $166.3 \pm 9.0$  metric tons/km<sup>2</sup>; Figure 11) remained relatively stable from 2006 to 2009, while mean fish diversity ( $H'$ ) hovered around  $2.00 \pm 0.01$  SE between 2006-2008, but jumped to  $2.28 \pm 0.15$  SE in 2009 (Figure 12).

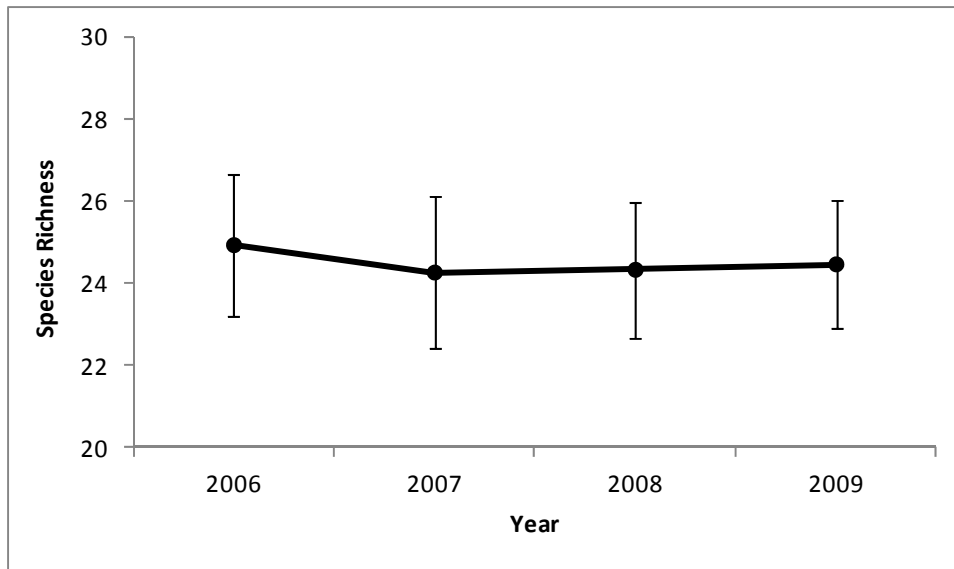


**Figure 9.** Fish species richness (no./125 m<sup>2</sup>) at Kalaupapa National Historical Park from 2006-2009. Error bars are one standard error of the mean.

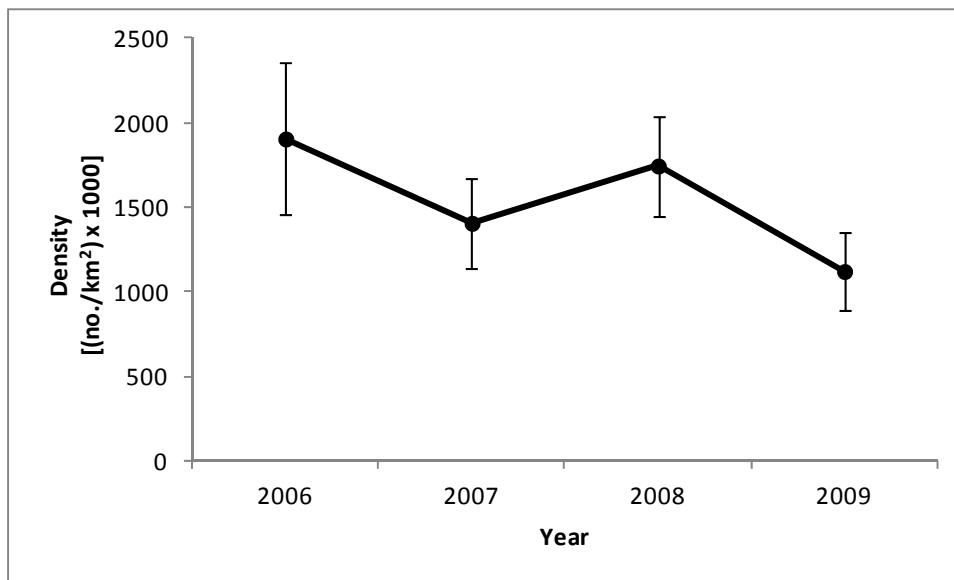


**Figure 10.** Fish density [(no./km<sup>2</sup>) x 1000] at Kalaupapa National Historical Park from 2006-2009. Error bars are one standard error of the mean.

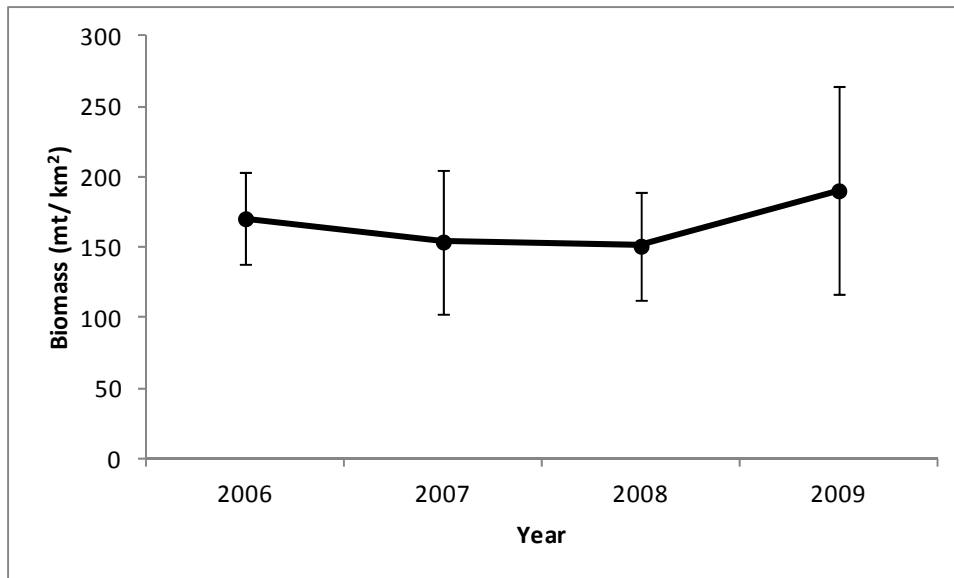


**Figure 11.** Fish biomass (mt/km<sup>2</sup>) at Kalaupapa National Historical Park from 2006-2009. Error bars are one standard error of the mean.

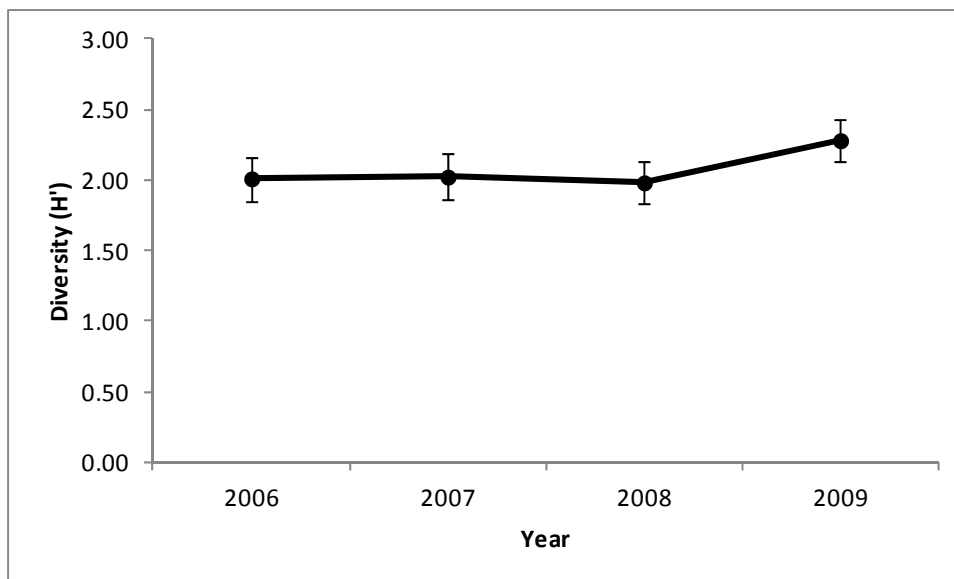


**Figure 12.** Fish diversity (H') at Kalaupapa National Historical Park from 2006-2009. Error bars are one standard error of the mean.

## Discussion

Survey results from 2009 indicated that high and low levels of fish species richness, density, biomass and diversity were patchily distributed throughout the park. Patches of high species richness were found in three locations: on the western side of the peninsula, near the northern tip of the peninsula, and near the eastern boundary of the park (Figure 3). The highest fish density values were concentrated near the northern tip of the peninsula, while consistently low values were found near the eastern and western boundaries of the park (Figure 4). In terms of biomass, two transects fell outside the norm: fixed transect 6, located on the northwestern coast of the peninsula, had approximately one fourth the biomass of any other transect, while at fixed transect 8, located at the northern tip of the peninsula, the biomass was almost three times higher than at any other transect (Figure 5). High and low fish diversity ( $H'$ ) values were distributed fairly evenly throughout the park (Figure 6).

The high density (Table 2) of the relatively small (up to about 7 cm, Hoover 2008) *C. vanderbilti* influenced the relative density versus biomass of the fish trophic groups. In terms of density, secondary consumers (including *C. vanderbilti*) accounted for approximately 77% of the individual fish observed in 2009 (Figure 7). However, secondary consumers accounted for just 43% of the biomass (Figure 8). This decrease was mainly compensated for by primary consumers, which constituted 44% of the biomass (but only 22% of the individual fish observed). A large portion of this biomass was attributed to the second most abundant taxon in the park, *Kyphosus* spp. (Table 2). These fish are relatively large, attaining sizes up to 60 cm (Randall 1996). The second most abundant species by biomass, and the sixth most common by density, was the introduced snapper *Lutjanus kasmira* (Tables 2 and 3). Introduced to Hawaii in 1955, *L. kasmira* has since become abundant throughout the archipelago (Friedlander et al. 2002). How *L. kasmira* interacts with native species, and whether it adversely affects local fish populations, is a controversial topic requiring further study. Current research, however, suggests that it may compete with native fish for shelter (Schumacher and Parrish 2005). Thus, its presence in Kalaupapa in such high numbers may be a cause for concern and should be monitored in the future.

Of particular ecological importance to the PACN parks are the apex predators. Worldwide, large apex predators have been on the decline with many, including sharks, disappearing at alarming rates (Worm et al. 2006). These (typically) large predators are important to the reef because their absence can cause dramatic shifts in the species composition and dominant taxa of a reef. At KALA, in 2009, apex predators accounted for just 1% of individual fish observed (Figure 7), but constituted 13% of the biomass (Figure 8). In addition, three of the top ten most abundant species by biomass were apex predators (Table 3). This relatively high apex predator biomass could be partly due to the light fishing pressure at Kalaupapa (Tom 2010).

While fish species richness (Figure 9) and fish biomass (Figure 11) remained stable from 2006-2009, and fish diversity showed a slight increase in 2009 (Figure 12), fish density (Figure 10) has declined since monitoring was initiated. Further data collection and rigorous statistical analyses in subsequent reports will help us learn if this decline is significant and a cause for concern.



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## Appendix A: Database Queries Used to Generate Reports

### STATUS MAPS (for all transects):

|    | Data              | Excel File               | Columns in Excel File                           | Database Query                   |
|----|-------------------|--------------------------|-------------------------------------------------|----------------------------------|
| 1. | Species richness  | Fish Summary Status Maps | Sp Richness                                     | qs_f021_Fish_Summary_by_Transect |
| 2. | Density/abundance | Fish Summary Status Maps | Density (Num/km2)x1000                          | qs_f021_Fish_Summary_by_Transect |
| 3. | Biomass           | Fish Summary Status Maps | Biomass (mt/km2)<br><i>Note: mt=metric tons</i> | qs_f021_Fish_Summary_by_Transect |
| 4. | Diversity         | Fish Summary Status Maps | Div                                             | qs_f021_Fish_Summary_by_Transect |

### TREND LINE GRAPHS (fixed transects only (combined); units the same as in status maps):

|    | Data              | Excel File             | Columns in Excel File | Database Query                       |
|----|-------------------|------------------------|-----------------------|--------------------------------------|
| 1. | Species richness  | Fish_SpRichness_Trends | All years             | qs_fr041_Fish_Species_Richness_Trend |
| 2. | Density/abundance | Fish_Density_Trends    | All years             | qs_fa041_Fish_Density_Trend          |
| 3. | Biomass           | Fish_Biomass_Trends    | All years             | qs_fb041_Fish_Biomass_Trend          |
| 4. | Diversity         | Fish_Diversity_Trends  | All years             | qs_fd041_Fish_Diversity_Trend        |

### PIE CHARTS (for all transects combined):

|    | Data                           | Excel File         | Columns in Excel File    | Database Query                  |
|----|--------------------------------|--------------------|--------------------------|---------------------------------|
| 1. | Trophic composition by density | Fish_Trophic_Chart | Primary, Secondary, Apex | qs_ft001_Fish_Trophic_Abundance |
| 2. | Trophic composition by biomass | Fish_Trophic_Chart | Primary, Secondary, Apex | qs_ft002_Fish_Trophic_Biomass   |

### TABLES (for all transects combined):

|    | Data                       | Excel File           | Columns in Excel File                    | Database Query                |
|----|----------------------------|----------------------|------------------------------------------|-------------------------------|
| 1. | Metadata                   | Metadata             | All columns                              | qs_md001_Metadata_by_Transect |
| 2. | Top ten species by density | Fish_Top_Ten_Density | TaxonName, SumOfNum_km2 x 1000, Consumer | qs_fa061_Fish_Top_Ten_Density |
| 3. | Top Ten species by biomass | Fish_Top_Ten_Biomass | TaxonName, SumOfBio_mt/km2, Consumer     | qs_fb061_Fish_Top_Ten_Biomass |