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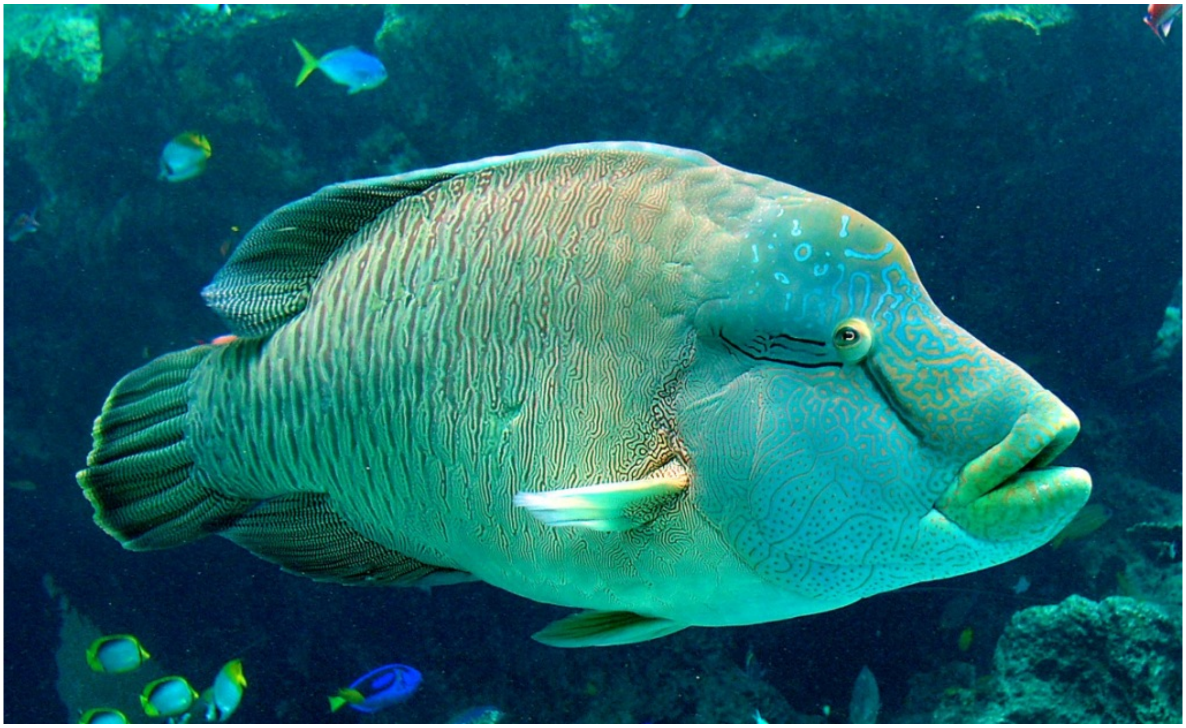
October 2015

Status Review Report:
Humphead Wrasse (*Cheilinus undulatus*)



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Pacific Islands Fisheries Science Center
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U.S. Department of Commerce

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Status Review Report:
Humphead Wrasse (*Cheilinus undulatus*)

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EXECUTIVE SUMMARY

This status review was conducted in response to a petition to list the humphead wrasse under the Endangered Species Act (ESA) (WildEarth Guardians submitted to U.S. Secretary of Commerce, Acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service (NMFS or NOAA Fisheries), October 31, 2012, "Petition to list the humphead wrasse (*Cheilinus undulatus*) under the U.S. Endangered Species Act"). NMFS evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list a species. On February 28, 2013, NMFS determined that the petition did present substantial scientific and commercial information, or cited such information in other sources, and therefore the petitioned action may be warranted. This finding was published in the *Federal Register* (78 FR 13614; February 28, 2013). Subsequently, NMFS initiated a status review of the humphead wrasse. This status review is comprised of two components. Part I: The "Biological Assessment and Identification of Threats" of the species, compiles the best available information on the status of the humphead wrasse as required by the ESA and identifies threats to the species' survival. Part II: The "Assessment of Extinction Risk" for the species, provides the methods and conclusions of the NMFS Extinction Risk Analysis (ERA) Team on the current and future extinction risks to the humphead wrasse.

The humphead wrasse is the largest living member of the family Labridae, with a reported maximum size of 229 cm total length (7.5 ft) and 190.5 kg (420 lb) (Marshall 1964); however, there are no confirmed records of this species greater than 150 cm fork length (Choat et al. 2006). The species is a protogynous hermaphrodite (i.e., adults can change sex from female to male), is long-lived (30 years for females and 25 for males), and occurs in naturally low densities in reef-associated areas throughout its geographical range in the Indo-Pacific (Sadovy et al. 2003a). Unfished or lightly fished areas have densities ranging from 2-27 individuals per 10,000 m^2 of reef (Sadovy et al. 2003a). In fished areas, densities are typically lower by tenfold or more and in some places fish no longer appear to be present (Sadovy et al. 2003a; Colin 2006; Sadovy 2006b; Unsworth et al. 2007).

Within territorial waters of the U.S. Pacific Islands, humphead wrasse are naturally rare/uncommon but are observed in slightly greater abundance than at many other islands and reefs within its biogeographic range. Although historical data for humphead wrasse are sparse or lacking, human population density and levels of fisheries exploitation most likely contribute to low abundances currently observed at many international locales including French Polynesia, parts of Fiji, Indonesia, Malaysia, and Tonga. Conversely, some sites that are remote or protected have higher observed densities, relatively speaking, and include parts of Australia's Great Barrier Reef, Maldives, New Caledonia, and Seychelles (Sadovy et al. 2003a).

The humphead wrasse possesses life history characteristics and ecology that makes it particularly vulnerable to fisheries exploitation. They include moderate-late maturation, long lifespan (up to 30 years), and predictable home range and resting sites. Additionally, the humphead wrasse is one of the highest-valued reef fish in commercial trade, fetching upwards of US$130-180/kg for

recent market prices (Johannes and Riepen 1995; Sadovy et al. 2003a; Pinnegar et al. 2006). A single, large 40 kg humphead wrasse can sell for over US$5,000 in the Hong Kong market (Erdman and Pet-Soede 1997). As such, the demand for humphead wrasse in international seafood markets has led to widespread declines, especially in regions where fisheries focus on meeting the demand of the live reef food fish trade (Sadovy et al. 2003b).

On the basis of information summarized in Part 1(Biological Assessment), the Extinction Risk Analysis (ERA) Team conducted a series of analyses that are presented in Part II. The following summaries report the conclusions of these analyses, while the substance and rationale are given in Part II.

Summary of Distinct Population Segment (DPS) Conclusions

Prior to evaluating the extinction risk of the species, the ERA Team examined the global population of humphead wrasse using the best available information to see whether any populations qualified as "distinct population segments" (DPSs) under the NMFS and U.S. Fish and Wildlife Service DPS Policy (61 FR 4722; February 7, 1996). Based on the criteria for discreteness and significance under the DPS Policy, delineation of distinct population segments was not supported. Therefore, the global population of the species was subsequently evaluated in terms of its risk of extinction.

Summary of "Significant Portion of its Range" (SPOIR) Conclusions

The ERA Team also analyzed whether a portion of the range of the species is "significant" and if its contribution to the viability of the species is so important that, without that portion, the species might not survive. Based on the best available information, no portion of the species' range was deemed a "significant portion of the range" (SPOIR). In other words, although the population within the Coral Triangle region (particularly Indonesia, Malaysia, and the Philippines) is considered the center or core of the species' biogeographic distribution, the status of the rest of the species outside of this area was not seen as dependent on the continued existence of the population in this core area.

Summary of Demographic Risk Analysis Conclusions

The ERA Team reviewed relevant biological and commercial information for the humphead wrasse to determine how demographic risks may be impacting the species, both now and in the foreseeable future. For the humphead wrasse species as a unit throughout its biogeographic range, the ERA Team concluded that the demographic factor of abundance had a low-to-moderate likelihood of contributing to the risk of extinction "now" (over 0-25 years) and a moderate-to-high likelihood of contributing to the risk of extinction in the "foreseeable future"

(26-50 years). The demographic factor of growth rate/productivity had a low likelihood now and a moderate likelihood of contributing to the risk of extinction in the foreseeable future. The demographic factors of spatial structure/connectivity had a no-to-low risk both now and the foreseeable future, and diversity had a low risk both now and in the foreseeable future. Certainty was judged to be medium regarding the information on abundance and growth rate/productivity now, and low regarding the other demographic factors now. Certainty was also judged to be low for all four demographic factors for the foreseeable future.

Summary of Threats Analysis Conclusions

The ERA Team reviewed relevant biological and commercial information regarding threats to the humphead wrasse. Out of the five ESA section 4(a) threat factors, the ERA Team identified only two factors: 1) overutilization for commercial, recreational, scientific, or educational purposes; and 2) the inadequacy of existing regulatory mechanisms as having a moderate likelihood of increasing the extinction risk of the species now. These factors as well as: 3) the present or threatened destruction, modification, or curtailment of its habitat or range; and 4) other natural or manmade factors affecting its continued existence were observed as having a moderate likelihood of increasing extinction risk in the foreseeable future. The fifth factor, disease or predation, was identified as having no, or only a small likelihood of increasing extinction risk. Certainty was judged to be medium for the information on all threats and time frames except for the foreseeable future, where, for the most part, information was viewed as having low certainty for overutilization, inadequacy of existing regulatory mechanisms, and other natural or manmade factors.

Although demographic factors such as abundance, and threats such as overutilization and inadequacy of existing regulatory mechanism were judged moderately likely to increase the species' extinction risk, such judgments qualified the likelihood of increases to extinction risk, not the magnitude of the increased risk. Increments to risk may be likely without the base risk or its increment being large as was concluded below.

Summary of Overall Extinction Risk Analysis Conclusions

After reviewing the best available information as summarized in this Status Review document, the ERA Team, drawing upon their professional knowledge, integrated the results of the demographic risks analysis and the threats assessment in a qualitative analysis of the overall risk of extinction. The Team noted that there is some likelihood for the demographic factors of abundance and growth rate/productivity contributing to the extinction risk of the species, especially because it is a naturally rare species. The Team also noted that there is some likelihood for threats related to overutilization and inadequacy of existing regulatory mechanisms contributing to the extinction risk of the species. However, the Team concluded that, though somewhat likely, the credible increments that each of these individually and collectively contribute to the overall extinction risk were too small to constitute an overall risk of extinction now to the humphead wrasse, as a species unit over its entire range, with high relative certainty regarding the available information. The Team also concluded that there was a low overall risk of extinction for the humphead wrasse in the foreseeable future, with relatively low certainty regarding the available information. Despite its natural rarity and depressed abundance in certain areas, this no-to-low overall risk of extinction is based primarily on the species' sustained widespread distribution throughout most of its known range, and its recent effective protection from exploitation at a variety of localities under both U.S. and foreign jurisdiction.

CONTENTS

1.0. INTRODUCTION

1.1. Scope and Intent of this Document

This report documents the status review conducted in response to a petition[1] to list the humphead wrasse (*Cheilinus undulatus*) under the Endangered Species Act (ESA). Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). The National Marine Fisheries Service (NMFS or NOAA Fisheries) decided that the petition had sufficient merit for consideration and that a status review was warranted (78 FR 13614; February 28, 2013). The ESA stipulates that listing determinations should be made based on the best scientific and commercial information available. NMFS assigned an Endangered Species Biologist in the Protected Resources Division of the NMFS Pacific Islands Regional Office (PIRO) to undertake a biological assessment of the humphead wrasse. This consisted of a literature review of the species' biology and current population status as well as an identification of threats to the species. Using this biological assessment, PIRO convened a team of four biologists to conduct an Extinction Risk Analysis (ERA) for the humphead wrasse. Team members included Dr. Christofer H. Boggs (NMFS Pacific Islands Fishery Science Center (PIFSC), Dr. Edward E. DeMartini (NMFS PIFSC), Dr. Robert E. Schroeder (NMFS PIRO), and Michael S. Trianni (NMFS PIFSC). This status review report provides the biological assessment, summarizes the threats to the species, and documents the extinction risk analysis.

1.2. Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, two key questions must be addressed:

1) Is the entity in question a "species" as defined by the ESA?
2) If so, is the "species" threatened or endangered?

Section 3 of the ESA defines a "species" to include "any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature." Section 3 further defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

NMFS considers a variety of information in evaluating the level of risk faced by a species in deciding whether the species is threatened or endangered. Important considerations include: 1) absolute numbers of individuals and their spatial and temporal distribution, 2) current abundance

[1] WildEarth Guardians to U.S. Secretary of Commerce, Acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service, October 31, 2012, "Petition to list the humphead wrasse (*Cheilinus undulatus*) under the U.S. Endangered Species Act."

in relation to historical abundance and carrying capacity of the habitat, 3) any trends in abundance, 4) natural and human influenced factors that cause variability in survival and abundance, 5) possible threats to genetic integrity, and 6) recent events (e.g., a change in management) that have predictable short-term consequences for abundance of the species. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations (NMFS 2013).

Under section 4(a)(1) of the ESA, NMFS must determine whether one or more of the following factors is/are responsible for the species' threatened or endangered status:

(A) The present or threatened destruction, modification or curtailment of its habitat or range;
(B) Overutilization for commercial, recreational, scientific, or educational purposes;
(C) Disease or predation;
(D) The inadequacy of existing regulatory mechanisms; or
(E) Other natural or human factors affecting its continued existence.

The determination of whether a species is threatened or endangered must be based on the best available scientific and commercial information regarding its current status, after taking into consideration measures that are being made to conserve the species.

1.3. Summary of Information Presented by the Petitioners

The WildEarth Guardians' petition asserts that the humphead wrasse has declined dramatically due to its vulnerability to fishing. The petitioners assert that as a naturally rare to uncommon species, its biological characteristics (long life, late sexual maturation, hermaphroditism, and strong site fidelity, etc.) make it particularly vulnerable to even minimal fishing pressures.

The petitioners claim that this species is imperiled throughout all or a significant portion of its range due to impacts from four of the five section 4(a)(1) listing factors. Within ESA Factor (A), the petitioners state that seven threats are contributing to the decline of the humphead wrasse. These, sometimes interdependent threats, are: 1) destruction of coral reefs; 2) coastal development; 3) watershed-based pollution; 4) sedimentation; 5) destructive fishing practices; 6) human population growth; and 7) habitat degradation from climate change such as increased water temperature, acidification, and increasingly destructive storms. Each of these threats, according to the petitioner, is degrading reef ecosystems, causing coral bleaching, and other impacts. For ESA Factor (B), overexploitation in the live reef food fish trade and the vulnerability of the species to spearfishing at night are the drivers for commercial and recreational overutilization. Three threats are contributing to ESA Factor (D): inadequate protection from human exploitation, inadequate protection of habitat, and inadequate protection from climate change. Finally, for ESA Factor (E), there are five threats that are negatively acting on the species. These include: life history factors such as long life, late sexual maturation, seasonal spawning aggregations, and hermaphroditism make the species more vulnerable to disturbances and fishing pressures; small population size and natural rarity; effects from climate change such as warming ocean temperatures and more extreme weather events; ocean acidification causing a decline in the oceans' pH level; and lastly, effects from any or all of the aforementioned threats could work synergistically to cause a greater reduction in humphead wrasse populations than would be expected from simply the additive impacts of individual threats (WildEarth Guardians 2012).

The petitioner also asserts that the humphead wrasse's inclusion in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), as well as a listing of "endangered" by the International Union for Conservation of Nature (IUCN), have been unsuccessful in protecting the species from further decline. The petitioners therefore claim that listing the humphead wrasse under the ESA would provide the species with much needed regulatory protection.

1.4. Species of Concern

In recognition of concern for the status of and threats to the species, NMFS added the humphead wrasse to its Species of Concern list in 2004. Though the "Species of Concern" status does not carry any procedural or substantive protections under the ESA, it can draw proactive attention and conservation action to the species.

PART I: BIOLOGICAL ASSESSMENT AND IDENTIFICATION OF THREATS OF THE HUMPHEAD WRASSE (*CHEILINUS UNDULATUS*)

Photo Credit: Dr. John E. Randall

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2.0. LIFE HISTORY AND ECOLOGY

2.1. Identifying Characteristics and Taxonomy

The humphead wrasse, *Cheilinus undulatus* (Rüppell, 1835), is the largest member of the family Labridae (Sadovy et al. 2003a) and one of the largest bony fishes occurring on coral reefs (Colin 2010). Found throughout the Indo-Pacific Ocean, the humphead wrasse is distinguished from other reef fishes, including other wrasses, due primarily to its large size. The humphead wrasse has a reported maximum length of 229 cm total length (TL) (7.5 ft) and weight of 190.5 kg (420 lbs) (Marshall 1964; Myers 1989; Lieske and Myers 1994; Donaldson and Sadovy 2001; Westneat 2001; Sadovy et al. 2003a; Russell 2004); however, there are no confirmed records of this species greater than 150 cm fork length (FL) (Choat et al. 2006 [TL is measured from the tip of the snout to the tip of the longer lobe of the caudal or tail fin, whereas FL is measured from the tip of the snout to the end of the middle caudal fin rays (i.e., where the fork of the tail begins); TL is longer than FL]). Other prominent features include a bulbous hump on the forehead of larger individuals of both sexes, large fleshy lips (Myers 1999), and intricate markings around the eyes (Marshall 1964; Bagnis et al. 1972; Sadovy et al. 2003a). The development of the cephalic hump is related to body size (i.e., can be much larger for adult males) and is visible at 37 cm TL, with all individuals ≥ 75 cm TL exhibiting a distinctive hump, irrespective of sex (Liu and Sadovy de Mitcheson 2011). Therefore, *C. undulatus* does not show obvious sexual dimorphism of the forehead extension, meaning that it is not a reliable criterion for differentiating males and females. The species has 9 (IX) dorsal fin spines, 10 dorsal fin rays, 3 (III) anal fin spines, and 8 anal fin rays (Sadovy et al. 2003a).

Small juveniles are pale gray/green with large dark spots on some of the scales that produce a series of broad dark bands, interspersed with narrower white bands along the length of the body. A pair of distinctive parallel black lines is visible before and after the eye (Figure 1 [Sadovy et al. 2003a]). Colin (2006) notes that juvenile *C. undulatus* resemble juvenile *C. trilobatus* and *C. chlorurus*, with similar shape, some resemblance in coloration, similar swim fashion, and can all occur in the same habitat. The author notes that the similarities with these two more common species can result in confusion and misidentification of juvenile *C. undulatus*.

Adults are olive green to blue-green with large scales (up to 10 cm in diameter). These large scales are apparently strong enough that a spear will often fail to penetrate them (Thaman 1998). A narrow dark bar on each scale breaks into irregular dark lines anteriorly on the body with growth (Randall 2005). The head is a blue-green to blue with irregularly wavy yellowish lines (Sadovy et al. 2003a) with the same two slightly oblique black lines extending posteriorly from the lower half of the eye, often with two more black lines extending from the eye to the rear part of the upper lip (Randall 2005). These distinctive patterns of lines makes identifying individual fish possible if the head pattern and spots can be seen or photographed. There is no apparent sexual dichromatism or permanent difference in color between sexes (Sadovy et al. 2003a); temporary color differences between males and females are seen during reproduction (Colin 2010). Numerous pale yellowish-green lines cross the median fins; dorsal and anal fins of adults pointed posteriorly; caudal fin rounded; pelvic fins reaching anus in juveniles, extending beyond origin of anal fin in adults (Randall 2005).

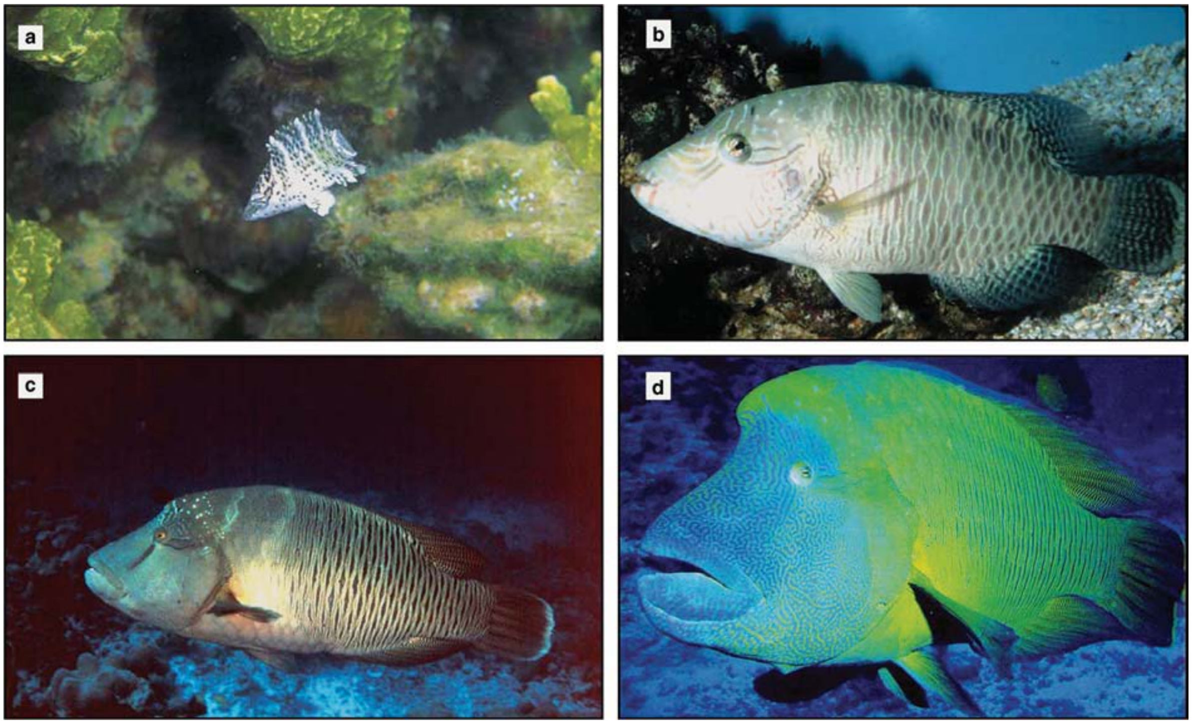

Figure 1.--Morphological and color changes in *C. undulatus* with growth. All phases have a pair of distinctive lines running through the eye. (a) Small juveniles are light with dark bands; (b) larger juveniles (~25 cm TL) are pale green; (c) adults are more olive to green and (d) the largest fish have a pronounced forehead and are more blue-green to blue (Source: Sadovy et al. 2003a – photographs by J.E. Randall [a, b, c] and R.F. Myers [d]).

The taxonomic classification is as follows:

Kingdom:	Animalia
Phylum:	Chordata
Class:	Actinopterygii
Order:	Perciformes
Family:	Labridae
Genus:	*Cheilinus*
Species:	*undulatus*

The species is known by common names that include humphead, humphead wrasse, and Napoleon wrasse. Additional common names include: giant wrasse; Maori wrasse; truck wrasse; undulate wrasse (Russell 2004); tangison and tasen guaguan in the Chamorro language of the Mariana Islands (CNMI Coastal Resources Management Office 2011); lalafi, tagafa, or malakea in American Samoa (American Samoa E.O. 002-2012); maml in Palau (Colin 2010); variivoce in Fiji (Thaman 1998); so-mei in Hong Kong, southern China, and Taiwan; mameng in the Philippines; Ikan Napoleon in Indonesia (Koesharyani et al. 2005; Zafran et al. 2005); meganemochino-uo in Japan (Koesharyani et al. 2005; Zafran et al. 2005); and merer or ma'a'm in the Pohnpeian language of the Caroline Islands (CRMO 2011; Wikipedia 2013). A more comprehensive list of common names can be found at the Fishbase web site (www.Fishbase.org) or from Sadovy et al. (2003a). The existence of multiple names in a language is an indication of the important cultural significance of the species as well as the identification of size differences within the species (CRMO 2011).

2.2. Habitat

Coral reef ecosystems of the Indo-Pacific Ocean are among some of the most diverse ecosystems on the planet with over 3,000 species of fishes recorded from the region (Bellwood et al. 2003). The humphead wrasse is widely distributed in low densities on all types of coral reef environments and nearshore habitats throughout much of the tropical Indo-Pacific. Humphead wrasse are most often encountered on outer reef slopes and reef passes/channels at depths of only a few meters to at least 60 m (Randall 1978); other reports document humphead wrasses to depths of up to 100 m (Russell 2004; Zgliczynski et al. 2013). Personal observations from NMFS biologists that are familiar with the species note that the species has been observed on deep dives and caught at depths > 100 m and up to ~180 m by deep gillnet (Gerry Davis, pers. comm.). Existing data on the recorded depth observations of humphead wrasse are either qualitative or incompletely analyzed.

2.2.1. Juvenile Habitat

Both seagrass beds and coral reefs have been reported to provide a nursery habitat for post-settlement and juvenile humphead wrasse (Sadovy et al. 2003a; Russell 2004). Several studies note their association with branching staghorn corals (*Acropora* spp.); in Palau, shallow inshore habitats with abundant branching coral mixed with foliose macroalgae are nursery habitats for *C. undulatus* (Tupper 2007), whereas in Tanzania, juveniles are commonly observed inhabiting seagrass beds. Additionally, when seagrass beds are present, densities of juvenile humphead wrasse are significantly higher on coral reefs than in areas without nearby seagrass beds (Dorenbosch et al. 2006). Juveniles are also observed in murky outer river areas with patch reefs, shallow sandy areas adjacent to coral reef lagoons, and in mangroves (Randall 1955; Randall et al. 1978; Myers 1989; Sadovy et al. 2003a; Myers 1999).

2.2.2. Adult Habitat

Unlike juveniles, adults are more commonly observed inhabiting offshore habitats along steep outer reef slopes, reef drop offs, channel slopes, reef passes, reef flats, and lagoonal reefs to depths of up to at least 100 m (Gerry Davis, pers. comm., Myers 1989; Sadovy et al. 2003a). Fish size and abundance are also correlated with habitat type, with the largest fish and most dense groups of humphead wrasses observed on barrier reefs and passes (Figure 2). In coastal, middle reefs and lagoon areas, smaller fish (< 50 cm TL) are typically observed among branching staghorn corals ([Sadovy et al. 2003a] Figure 3).

As far as is known, all reproduction takes place in temporary aggregations that form regularly on the shelf edge/reef drop-off area at consistently used locations along stretches of reef. Therefore, on a regular basis all adults, whether living in shallow water or in deeper reef slope waters, are expected to visit the shelf edge area to participate in spawning (Y. Sadovy, pers. comm.).

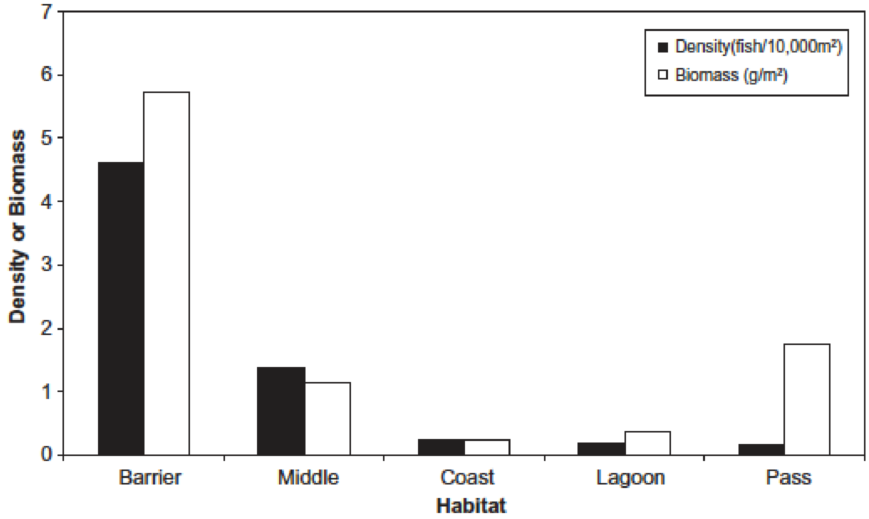

Figure 2.--Abundance (fish/10,000 m^2) and biomass (g/m^2) of *C. undulatus* according to habitat in New Caledonia and Tuamotu Archipelago (French Polynesia). (Source: Sadovy et al. 2003a)

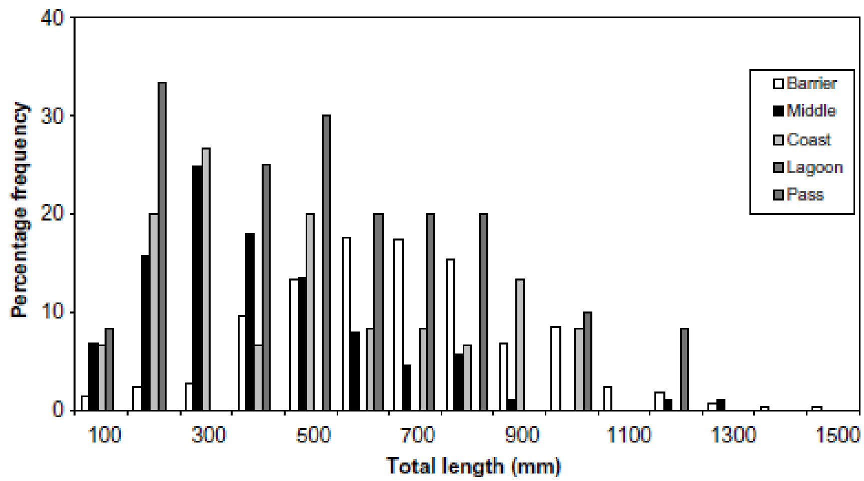

Figure 3.--Size (total length in mm) distribution of *C. undulatus* by habitat type in relatively unfished study sites in New Caledonia and Tuamotu Archipelago (French Polynesia). Distributions are given as frequencies (cumulative frequencies for each habitat is 100%) to allow for comparisons across habitats. (Source: Sadovy et al. 2003a)

2.3. Movement and Behavior

The numbers of fish found together – juveniles with juveniles, adults with adults, and numbers of fish in fished versus unfished areas – are variable in the literature. According to Sadovy et al. (2003a), juveniles are typically solitary, wary, and difficult to approach, though they occasionally can be found in small groups of 3-4 individuals within <10 m from one another (Pat Colins, pers. comm.). Adults are typically observed solitary or paired (Myers 1989; Sadovy et al. 2003a), but have also been noted in groups of 3-7 individuals (Donaldson 1995; Sadovy et al. 2003a). Additionally, small social units can be observed moving together in less heavily fished areas, while lone and more wary individuals are more often noted in heavily fished areas (Sadovy et al. 2003a). In Sasanhaya Bay, Rota, Commonwealth of the Northern Mariana Islands, a social group consisting of a single male and several females is frequently observed (Donaldson 1995). Similar behavior has been observed in the Yaeyama Islands of Japan (Donaldson 1995 citing J.T. Moyer, pers. comm.). Based on mensurative *in situ* observations humphead wrasse display site fidelity and predictable home ranges with the same individuals, identifiable by distinct head markings, observed along the same stretches of reef for extended periods (although the length of these periods are not defined). Many commercial dive sites have a "resident" humphead wrasse (Sadovy et al. 2003a; Russell 2004). Additionally, adult humphead wrasse often use a consistent resting place (i.e., cave or crevice) at night or when threatened (Bagnis et al. 1972; Myers 1989; Thaman 1998; Myers 1999; Donaldson and Sadovy 2001; Sadovy et al. 2003a; Chateau and Wantiez 2007).

2.4. Home Range

Factors such as sex, age, and size of the fish directly influence the home range size of the humphead wrasse, with smaller-bodied fish using a fraction of the area occupied by adults (Sadovy et al. 2003a citing T.J. Donaldson, unpublished data). A single juvenile (45 cm FL) humphead wrasse that had been surgically implanted with an ultrasonic transmitter in New Caledonia moved at least 20-200 m every day and had an estimated home range size of at least 50,000 m^2 (Chateau and Wantiez 2007). In Palmyra Atoll, 19 acoustically tagged juveniles and adults (ranging in length from 27 to 109 cm TL) had home range sizes of 800 m^2 to 19,000 m^2 with smallest home ranges occupied by juveniles, intermediate ranges for adult males, and largest ranges occupied for adult females (Weng et al. in press).

Within a home range, a number of physical factors (wind, water agitation, turbidity, light, etc.) may influence fish behavior (active vs. sedentary) and activity type (cleaning, food search), as well as the biotope visited (seagrass beds vs. coral heads, position in the water column). Though speculative, it is possible that variations in these physical factors may affect the spatial patterns of the fish's activity and the size of its space used (Chateau and Wantiez 2007).

2.5. Foraging Ecology

The humphead wrasse is a diurnal carnivore, feeding during the day and sleeping at night (Durville et al. 2003; Gillbrand et al. 2007). Much of its prey is found in sand or rubble habitats where it feeds on a variety of molluscs, small fishes such as gobies, moray eels, sea urchins, crustaceans, brittle stars, starfish, and other invertebrates (Randall et al. 1978; Myers 1989; Randall et al. 1997; Thaman 1998; Sadovy et al. 2003a; Choat et al. 2006). Similar to other wrasse (Labridae), humphead wrasses forage by turning over or crushing rocks and rubble to reach cryptic organisms (Pogonoski et al. 2002; Sadovy et al. 2003a citing P.S. Lobel, pers. comm.). The thick fleshy lips of the species appear to absorb sea urchin spines, and the pharyngeal teeth easily crush heavy-shelled sea snails in the genera *Trochus* spp. and *Turbo* spp. (Myers 1989).

The humphead wrasse is also one of the few predators of toxic animals such as boxfishes (Ostraciidae), sea hares (Aplysiidae), and the crown-of-thorns starfish (*Acanthaster planci*) (Randall 1978; Myers 1989; Thaman 1998; Sadovy et al. 2003a). As such, the humphead wrasse plays an important ecological role as a top-level consumer by structuring the benthic community (IUCN 2007). Consumption of toxic species in certain areas, particularly Tahiti, Tuvalu, New Caledonia, the Tuamotu Archipelago (French Polynesia), Marshall Islands, and the Federated States of Micronesia can cause the humphead wrasse to be ciguatoxic to humans (Randall 1958; Randall et al. 1978; Randall 1979; Lewis 1986; Myers 1989; Dalzell 1992; Dalzell 1994; Sadovy 1998; Myers 1999; Sadovy et al. 2003b; Sadovy 2006b).

2.6. Spawning

Field reports reveal variable humphead wrasse spawning behavior, depending on location (Sadovy et al. 2003a; Colin 2010). Spawning can occur between several and all months of the year, coinciding with certain phases of the tidal cycle (usually after high tide) and possibly lunar cycle (Sadovy et al. 2003a; Colin 2010). Spawning can reportedly occur in small (< 10 individuals) or large (> 100 individuals) groupings, which can take place daily in a variety of reef types (Sadovy et al. 2003a; Russell 2004; Sadovy de Mitcheson et al. 2008; Colin 2010). Humphead wrasse can spawn daily at a local spawning site(s) (i.e., a "resident" spawner) (Domeier and Colin 1997), or migrate many miles to aggregate at reproductive sites (Pet and Pet-Soede 1999). Males may return daily to spawning areas for up to seven consecutive days (Sadovy et al. 2003a; Colin 2010) with males arriving first to patrol areas of open water along the reef slope. Male courtship involves posturing behavior with color changes and distinctive displays of the dorsal, caudal, and anal fin (see Appendix II and Colin 2010). Spawning is evidently always associated with drop-off outer reef areas (Y. Sadovy, pers. comm.).

Efforts to identify and study spawning behavior of humphead wrasse have been conducted at Palau (Colin 2010), the Great Barrier Reef in Australia (Colin 2010 citing J.H. Choat personal observation), New Caledonia (Chateau and Wantiez 2007) and Wake Atoll (R. Muñoz, pers. comm.). In Palau, more than 50 resident aggregations of *C. undulatus* were anticipated to exist along the outer barrier reef, with groups of up to 150 individuals (10-15 males/100 plus females) observed along the reef slope in a loose aggregation (Colin 2010). During an average 60-minute spawning session, females rise to pair-spawn with a posturing male, releasing gametes in a relatively sedate fashion lasting 3-5 seconds near the water's surface. Dominant males mated with 10-15 females daily and no same-day multiple spawning by females was observed. In Palau, the smallest female observed to spawn eggs was estimated to be about 35 cm TL (Colin 2010).

2.7. Settlement

Data from captive rearing programs indicates that egg diameter ranges from 0.62-0.67 mm, and newly hatched larvae are 1.5-1.7 mm TL (Slamet and Hutapea 2005). Eggs are spherical and lack pigment (Sadovy et al. 2003 citing P.L. Colin unpublished data). Little information is available regarding this species' larval dispersal in the wild (Poh and Fanning 2012). However, in unpublished work Colin (P.L. Colin pers. comm.) found that eggs of humphead wrasse moved slowly off the western barrier reef of Palau over a few hours in tidal currents, then stalled before moving laterally along the reef. Some eggs are brought back in over the barrier reef, while others remain at sea, all in the first 12 hours after spawning.

Tupper (2007, citing M. Tupper unpublished data) asserts that humphead wrasse larvae settle out of the plankton at a size of 8 to 15 mm TL, with a mode of 12 mm TL (at an unspecified larval duration), and reach 35 mm TL or greater within 2 to 3 weeks post-settlement. Slamet and Hutapea (2005), however, indicate that growth of larvae is actually much slower. The authors report that captive larvae reach 50-60 mm TL in 6 months. Settlement varies among habitat types.

2.8. Maturation and Sex Ratio

Size at maturity for males and females is difficult to compare across studies because some measurements are reported as total length (TL) and others as fork length (FL). Sadovy et al. (2003a) estimates that females reach sexual maturity at around 5 years of age and 35-50 cm TL. Other histological studies estimate that sexual maturity is reached around 40-60 cm TL, which is estimated to be about 5-7 years of age (Pogonoski et al. 2002 and Russell 2004 citing Sadovy, unpub. data; Sadovy et al. 2011) (Table 1). Another study analyzing early gonadal development on 178 humphead wrasse specimens revealed that minimum body sizes for female and male sexual maturation were 65 cm and 84.5 cm TL, respectively (Sadovy de Mitcheson et al. 2010). However, the authors note that despite the results from this study, based on available information, it is suggested that the typical size of female sexual maturation for the humphead wrasse occurs at 40-50 cm TL (Sadovy de Mitcheson et al. 2010). Choat et al. (2006) estimated length at first maturity as 45-50 cm FL for females (6-7 years) and 70 cm FL (9 years) for males (Figure 4). Despite the apparent differences in estimated minimum size of female sexual maturation among the different studies and locations, the age at first maturity is relatively late, representing about 20% of the female life span as opposed to 5-6% of the female life span observed in other reef fishes with life spans in excess of 30 years (Choat and Robertson 2002).

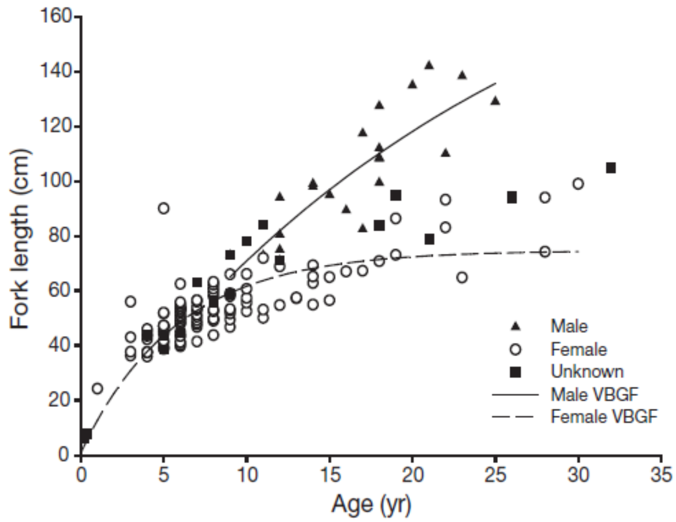

Figure 4.--Size at age plot partitioned by sex with fitted von Bertalanffy growth function (VBGF) curves. Size at t_0 constrained to 0. “Unknown”: samples in which sex was not verified. (Source: Choat et al. 2006)

As for the distribution of age frequencies, Choat et al. (2006) sampled 164 individuals from northeastern Australia and found the sample population to be dominated by young females with a modal size peak at 50 to 70 cm FL. Sadovy et al. (2003a) also report a female bias from sex ratio of samples and fish observed in the field. While males have two pathways of development (either directly from the juvenile phase or via sex change from an adult female to adult male, known as protogyny (Sadovy et al. 2003a)), size at age distribution confirms that the oldest members of the population are females in the 80 to 90 cm TL range (Choat et al. 2006). Though individuals in this size range are rare, these females have very large ovaries and thus could contribute significantly to the spawning stock (Choat et al. 2006).

Table 1.--Compilation of *C. undulatus* life history characteristics from the published literature for females, males, and unspecified gender (Uns).

Sampled Location	Max (cm)			Max Weight (kg)	Max Age (yr)		Length at maturity (FL or TL) (cm)			Age at maturity (yr)		Reference & Notes
	Female	Male	Uns	Uns	Female	Male	Female	Male	Uns	Female	Male	
Australia (Great Barrier Reef)					30							Andrews et al. in review. Otoliths from 94 cm TL female measured 28 (11-30 peak) years
Australia (Great Barrier Reef)		150 (FL)			30	25	45-50 (FL)	70 (FL)		6-7	9	Choat et al. 2006.
Australia (Hayman Island, Whitsunday Group, North Queensland)			229	190.0								Marshall 1964; Myers 1989; Choat and Bellwood 1994; Choat et al. 2006 citing Marshall 1966; J.H. Choat noted that Marshall did not examine the fish. Choat et al. 2006 note there are no confirmed records of this species > 150 cm FL
Guam (Hanom)	133.7			48.1								Guam Fishermen's Cooperative Association (GFCA) 2013
Guam (Inarajan)	130.9			47.4								GFCA 2013
Guam (South)		134.2		44.7								GFCA 2013
Indonesia							65 (TL) 40-50 (TL)	84.5 (TL)				Sadovy et al. 2003a; Sadovy de Mitcheson et al. 2010. Author noted size may be skewed due to sample size and that female sexual maturation is more widely accepted to occur at 40-50 cm TL.
Papua New Guinea							52 (TL)					Sadovy et al. 2003a; Sadovy de Mitcheson et al. 2010
Unspecified									40-60 (TL)			Pogonski et al. 2002 citing Sadovy, unpub. data; Sadovy et al. 2011
MAX	-	-	**229**	**190.5**	**30**	**25**	-	-	-	-	-	
AVERAGE/MEAN	-	-	-	-	-	-	-	-	-	**6.5**	**9**	

2.9. Age and Growth

The maximum age of humphead wrasse is estimated to be 30 years for females and 25 years for males (Sadovy et al. 2003a; Russell 2004; Choat et al. 2006; Andrews et al. in review) (Table 1). In public aquaria (Hong Kong and New Caledonia) three fish were known to live at least 16, 20, and 21 years (Sadovy et al. 2003 citing M. Stewart and M.K., pers. comm.). Humphead wrasses are among the largest, longest-lived bony fishes on tropical coral reefs (Choat and Robertson 2002; Choat et al. 2006).

As is common in wrasses, the species is a protogynous hermaphrodite, capable of changing sex from female to male around 9 years of age (Choat et al. 2006; Sadovy de Mitcheson et al. 2010). At around 6 months of age juveniles are approximately 5-6 cm TL (Slamet and Hutapea 2005), reaching 50 cm TL at approximately 7 years of age. As females reach sexual maturity growth slows, with few individuals observed > 100 cm TL. Male growth rates are approximately double those of females, resulting in relatively young but large males (Choat et al. 1996; 2006).

The largest reported humphead wrasse is from Hayman Island in the Whitsunday Group of North Queensland, Australia, measuring 229 cm TL (7.5 ft) and weighing 190.5 kg (420 lb) (Marshall 1964). In general, however, fish much larger than 150 cm TL are rarely recorded. The reasons for this are not clear but it is possible that larger fish are naturally rare, appear to be rare because they are wary, have become rare because they have been disproportionately fished out, occur predominantly in waters deeper than those typically visited by divers, or are not often targeted or caught by fishers (Sadovy et al. 2003a; SCRFA 2013).

2.10. Natural Mortality

The longevity of the species suggests that natural adult mortality is low (Sadovy et al. 2003a). Though the early post-settlement period typically has a high mortality level in fishes, it is likely that natural mortality drops rapidly after fish settle out from plankton (SCRFA 2013). As for mortality due to predation, there is refuge in size. Although adult humphead wrasses are most vulnerable during spawning, apex predators including sharks are not known to prey on adult humphead wrasse during this time (Colin 2010).

3.0. DISTRIBUTION AND ABUNDANCE

3.1. Geographic Range

The biogeographic range of the humphead wrasse spans from 30 °N to 23 °S latitude and includes the Red Sea south to Mozambique in the Indian Ocean, from southern Japan in the northwest Pacific south to New Caledonia in the south Pacific and into the central Pacific Ocean including French Polynesia. The humphead wrasse has been recorded from many islands of Oceania, but appears to be absent from the Hawaiian Islands, Johnston Island, Easter Island, Pitcairn, Rapa, and Lord Howe Island with the exception of occasional waifs (Randall et al. 1978). Outside of the U.S. Pacific Island areas, the humphead wrasse is known to occur from the following foreign locales: Australia; British Indian Ocean Territory (Chagos Archipelago); Cambodia; China; Christmas Island (Australia); Cocos (Keeling) Islands; Comoros; Cook Islands; Disputed Territory (Paracel Island, Spratly Island); Djibouti; Egypt; Eritrea; Fiji; French Polynesia; Hong Kong; India; Indonesia; Israel; Japan; Kenya; Kiribati; Madagascar; Malaysia; Maldives; Marshall Islands; Mayotte; Federated States of Micronesia; Mozambique; Myanmar; Nauru; New Caledonia; Niue; Palau; Papua New Guinea; Philippines; Pitcairn; Samoa; Saudi Arabia; Seychelles; Singapore; Solomon Islands; Somalia; Sri Lanka; Sudan; Taiwan, Province of China; United Republic of Tanzania; Thailand; Timor-Leste; Tokelau; Tonga; Tuvalu; Vanuatu; Viet Nam; Wallis and Futuna; and Yemen (Sadovy et al. 2003a; Russell 2004; Chu et al. 2006; Gillett 2010 [Figure 5]).

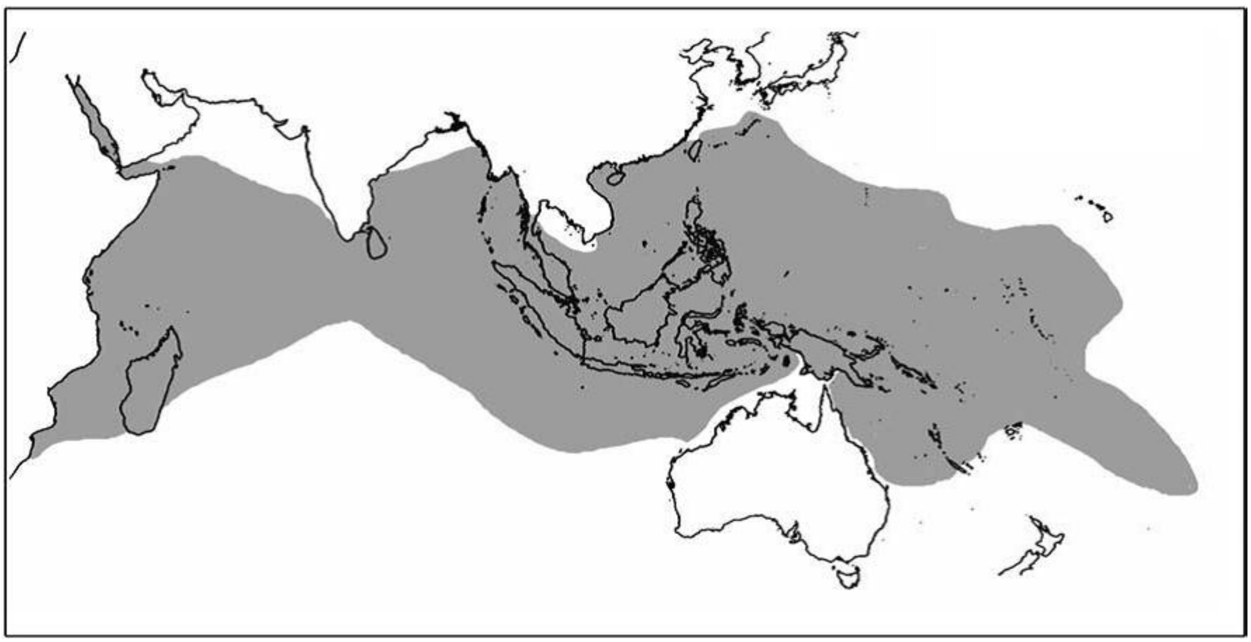

Figure 5.--Distribution map of *C. undulatus*. (Source: Sadovy et al. 2003a)

The Secretariat of the Pacific Community (SPC) Reef Fish Observatory, using distance-sampling underwater visual census methods between 2001 and 2012 surveyed 16 island countries (Figure 6) and observed a total of 591 humphead wrasse (SPC personal communication to Paul Dalzell, Western Pacific Regional Fishery Management Council). Usually four representative sites per country with active fisheries and varied habitats were surveyed along 24 transects per site (Pinca et al. 2009) with transects distributed equally among four main coral reef geomorphologic structures (sheltered coastal reef, intermediate reef, back reef, and outer reef). Average size for most of the countries was near to the overall mean of 50 cm, close to the size of sexual maturation. So in most of these islands, the observations included both adults and juveniles.

3.2. Geographic Range within the United States Pacific Island Areas

In the U.S. Pacific, humphead wrasses are found in the territories of American Samoa, the Commonwealth of the Northern Mariana Islands (CNMI), and Guam. In the U.S. Pacific Remote Island Area (PRIAs), the species is found in the Line (Palmyra Atoll, Kingman Reef, and Jarvis Island) and Phoenix (Howland and Baker) Islands, and at Wake Atoll.

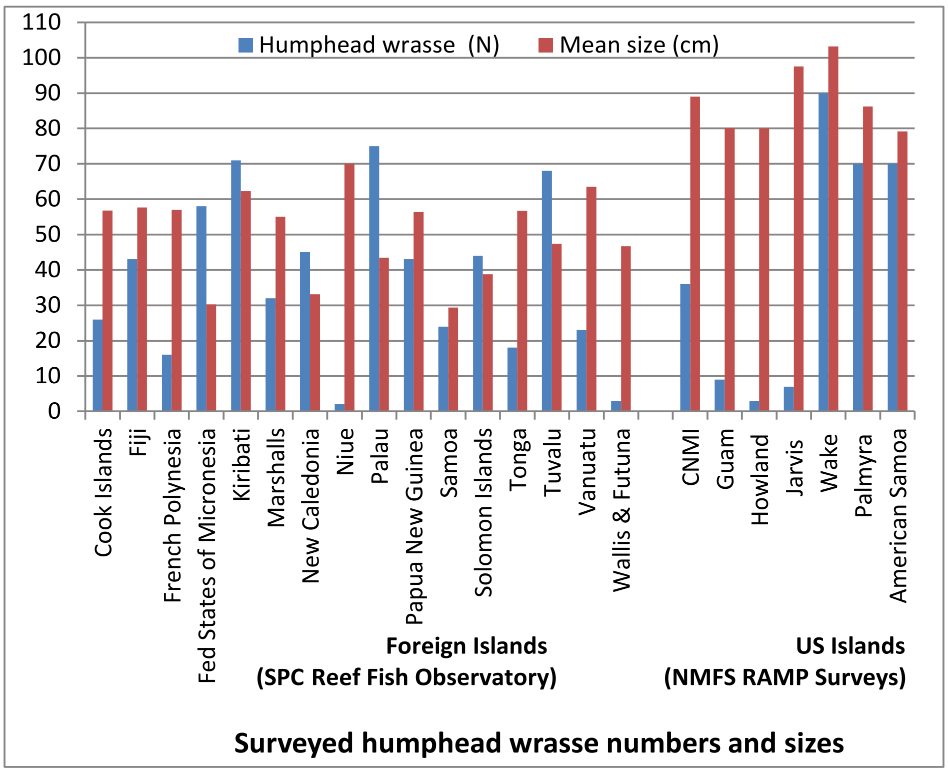

Figure 6.--Diver visual survey of humphead wrasse in the Pacific Islands conducted by the Secretariat of the Pacific Community (SPC) Reef Fish Observatory and by NMFS Reef Assessment Monitoring Program (RAMP).

3.3. Population Structure

Very little published genetic research is available on the humphead wrasse other than the results of sequencing the mitochondrial genome of the species (Qi et al. 2013). Research is currently underway that is analyzing *c*. 200 humphead wrasse spanning from the eastern Indian Ocean to Pohnpei, and from the Great Barrier Reef to the Marianas Islands. Preliminary analyses of mitochondrial DNA from a subset of samples from across the range suggest no deep genetic differentiation on the scale of ocean basins, though robust conclusions await final analyses of the complete dataset (Michael Dawson, pers. comm.). Additionally, no tagging or tracking studies of a scale sufficient to define population structure have been conducted.

Available suitable habitat is a major determinant of humphead wrasse distribution and some edge-of-range extirpations are suspected (Russell 2004). However, other than the larval rearing work of Slamet and Hutapea (2005), which indicates that Day 0-3 larvae are floating, Day 3-25 are free swimming, and Day 25-100 are close to bottom and hiding, little is known of the duration of the pelagic egg and larval stage.

3.4. Population Abundance and Biomass Estimates

Assessment of the status of tropical reef fishes, especially larger, wide-ranging fish like the humphead wrasse, is particularly challenging, whether by fishery-dependent or independent means. No long-term abundance indices for this species exist that could form the basis for a stock assessment based on fitting a population dynamics model to estimate historical or current abundance (Sadovy et al. 2007). As such, there is a large dependence on grey literature and anecdotal observations (Gillett 2010) as well as raw data.

There are no historical estimates (pre-1970s) of global or local abundance or biomass of humphead wrasse. When surveys first began on this species in the early 1970s, the species was generally characterized as being uncommon to rare in many places (Bagnis et al. 1972; Galzin et al. 1998). For example, in 1972 in Taiaro lagoon, a 9 km^2 uplifted lagoon (maximum depth of 27 m dominated by talus sand and small dispersed patch reefs) of Taiaro Atoll (Tuamotu Archipelago, French Polynesia), where fishing pressure was non-existent and fish diversity was high, abundance of humphead wrasse was estimated to be 1-2 fish per 10,000 m^2 (Galzin et al. 1998). This abundance remained unchanged during repeat surveys in 1992 and 1994 (Galzin et al. 1998). In the Society Islands of French Polynesia, humphead wrasses were also reported to be uncommon in the early 1970s (Bagnis et al. 1972; IUCN 2008 citing Galzin 1985). Past catch records for some locations, when compared to more current catch records, although the data are sparse, indicate that some populations were at one time greater than present day (IUCN 2008) (Table 2). Inferences regarding abundance from fishery dependent data are subject to uncertainty from effects of fishery targeting, fishing methods, size selectivity, fishery participation, regulation, and methods of collecting data. Such uncertainty is also true in relation to inferences made from underwater surveys when habitat information and survey methodology are not known.

Table 2.--Fishery dependent catch data by country. (Source: IUCN 2008)

Country	Catch Data	More Recent Catch Data	Change
Australia	0.23 mt catch per boat per year (1991)	0.12 mt catch per boat per year (1998)	50% decline
Fiji	22.5 mt annual catch (1994)	3.5 mt annual catch (2003)	> 80% decline
Malaysia	3.3 mt annual catch (1995)	0.2 mt annual catch (2003)	> 90% decline
Palau	3.0-3.5 mt annually (mid-1980s)	< 0.3 mt (mid-1990s)	> 10 fold decline*

*IUCN (2008) notes a 10-fold decrease in market landings from Palau from the mid-1980s to mid-1990s, though fails to note that fishing with SCUBA-spear was banned in the early 1990s and may be directly linked to that stated decline. Additionally, due to lack of reef fish catch surveys in Palau, the observed decrease may be real or less than shown if landing were not monitored.

In the U.S., the Western Pacific Fisheries Information Network (WPacFIN) coordinates a voluntary creel survey in the Pacific Island Territories of American Samoa, Guam, and CNMI that includes both recreational and commercial fishing but contains useful expanded estimates of catch for humphead wrasse only for Guam (Figure 7). In the Territories, most reef fish species are lumped by family, or as "reef fish" for sale, and most fishermen and vendors do not identify juvenile and subadult humphead wrasse. As a voluntary program, creel survey changes may partially reflect changes in participation rather than catch, particularly as the spear fishermen who catch most of this species were largely absent from the creel survey after 2005, making the subsequent data unrepresentative of the true catch (Lindfield et al. 2014).

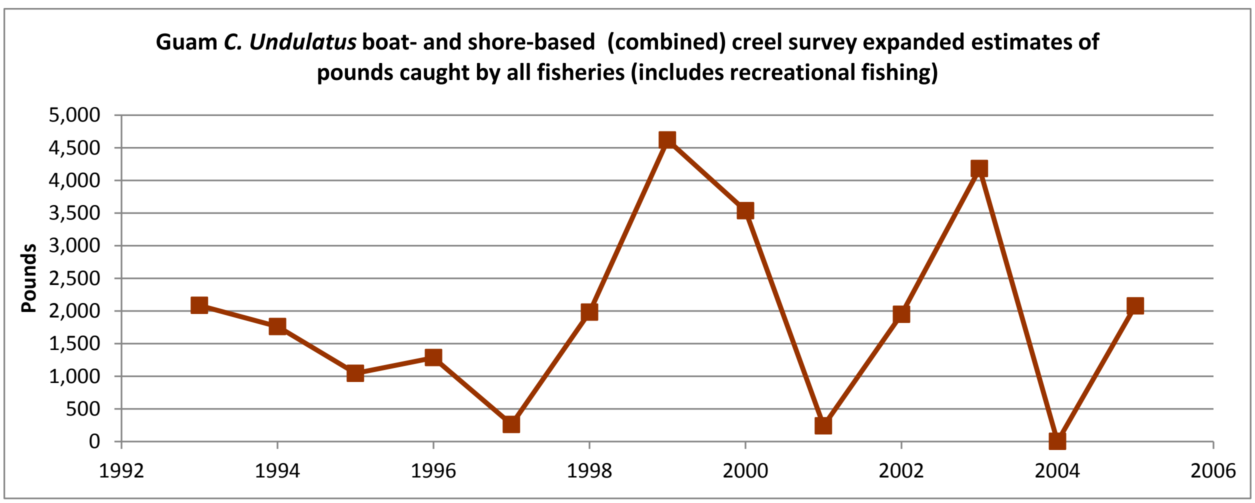

Figure 7.--Time series of expanded Guam creel survey data on humphead wrasse from the Western Pacific Fisheries Information Network (WPacFIN). (Source: NMFS PIFSC)

WPacFIN also provides adjusted (for % coverage of reporting) estimates of commercial landings for Guam from voluntarily submitted commercial receipt data spanning four years (Figure 8). These data suggest some increase in catch from 2007-2011, but again, changes in voluntary data submission may make the trend uncertain, especially with decreased participation after 2011. Nevertheless, the two time series sources of fisheries data for Guam do suggest a small but consistent catch of humphead wrasse over several decades. Additionally, the five-year (2007-2011) price average for the species in Guam was $2.79/lb (Guam Fishermen's Cooperative Association, pers. comm).

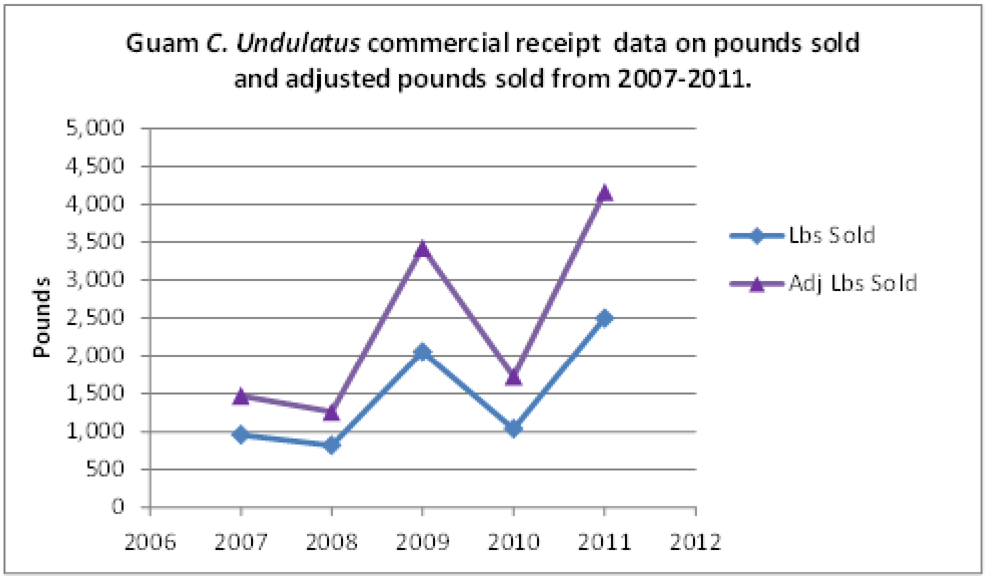

Figure 8.--Time series of reported and adjusted Guam commercial receipt data from WPacFIN. (Lowe et al. 2013)

In general, there are very few estimates of current (within the last few decades) global or local abundance or biomass of humphead wrasse. However, some estimates do exist for places such as Palau (Friedlander and Koike 2013) and for the U.S. Pacific Territories (NMFS PIFSC 2010; Brainard et al. 2012; Zgliczynski et al. 2013; NMFS PIFSC CRED unpublished). For Palau, Friedlander and Koike (2013) surveyed 90 transects totaling 43,417 hectares in fringing, back, fore, and patch reefs and estimated there are 37,071 humphead wrasse (standard deviation = 43-104,941 individuals). The NMFS Pacific Islands Fisheries Science Center (PIFSC) used visual survey data (methods discussed later) from their Coral Reef Ecosystem Division (CRED) Pacific Reef Assessment Monitoring Program (RAMP) to generate abundance estimates for humphead wrasse in American Samoa, CNMI, and Guam. For each island, numerical data were converted to biomass and multiplied by the estimated area available of the habitat stratum for the region. From these calculations, estimated biomass of humphead wrasse is: American Samoa: 34,860 lb; Guam: 39,200 lb; and CNMI: 40,184 lb (NMFS 2011; NMFS PIFSC CRED unpublished). These estimates were developed for reference in justifying annual catch limits (ACLs) for each region. Stock biomass has not been estimated for the PRIAs where CRED surveys have produced measures of abundance because, in the absence of fishing, catch limits are not needed in the PRIAs.

3.5. Global Population Trends

Although little is known about the population of *C. undulatus* at the global scale, estimates exist for certain regions throughout the species' range. According to CITES (2004; as reported by Gillett 2010), available fishery-independent and fishery-dependent data, including underwater visual censuses, fisher reports, dive-operator reports, and anecdotal information "collectively show declining populations in nearly all studied locations with suitable habitats subject to commercial fisheries."

3.6. Global Population Density

Efforts to estimate abundance and density of humphead wrasse have been completed in certain regions within the species' range (e.g., U.S. Pacific Islands) using underwater visual census techniques designed to quantify the abundance of these relatively rare/uncommon and wide-ranging fish. For many surveys, emphasis is placed on using techniques that are practical and provide repeatable and comparable data to assess changes in density over time (Colin 2006). Population trends and fish densities have also been compiled from fishermen reports, dive operator reports, fishery-based information, and anecdotal information (IUCN 2008).

Although humphead wrasses are widely distributed, natural densities are typically low, even in locations where habitats are presumably intact. Unfished or lightly fished areas have densities ranging from 2-27 individuals per 10,000 m^2 of reef (Sadovy et al. 2003a). At sites near human population centers or at fished areas, densities are typically lower by tenfold or more and in some locations humphead wrasse are rarely observed (Sadovy et al. 2003a; Colin 2006; Sadovy 2006b; Unsworth et al. 2007) (Table 3). When comparing abundance data across locations (Table 3), it should be noted that although data are available for a number of islands/nations the survey methods used to estimate abundance of humphead wrasse were not standardized across regions and in some instances, different survey methods were used across the survey period. In addition, the survey depths were often not standardized to a single depth. Both of these factors make comparisons across sites difficult.

Table 3.--Abundance estimates of *C. undulatus* from both fisheries-dependent and fisheries-independent data from the published literature given as number of individuals per 10,000 m^2 (mean given in parentheses); typical size range given in cm TL. Abundance estimates for U.S. Pacific Areas are found at the bottom of the table for comparison and in Figure 12 and Tables 4-9. (Note NA = not available.)

Sampled Location	Abundance	Fishing Pressure	Typical Size Range	Notes	Dates	Reference
Australia (Great Barrier Reef)	3.2-4.4	Low-Med	40-60, few > 90	NA	Pre-2003	Sadovy et al. 2003a citing J.H. Choat, pers. comm., and Pogonski et al. 2002
Australia (Queensland)	NA	NA	NA	0.23 kg catch per boat per year (1991) declined to 0.12 kg in 1998; 50% decline	1991- 1998	IUCN 2008 citing M. Samoilys, pers. comm.
Australia (Northern Queensland)	3.1-4.4	NA	NA	NA	NA	Pogonoski et al. 2002 citing H. Choat pers. comm.
Australia (Queensland - Swain and Pompey outer reefs)	NA	NA	NA	From post 1992, species not common and may no longer be found; species was very common in the 1950s and 1960s	1950s-1960s	IUCN 2008 citing O'Connell in litt., 1 May 2002
Cocos Keeling Islands	NA	Low	NA	Abundant	Pre-2003	Sadovy et al. 2003 citing J.H. Choat, pers. comm.
Fiji (Province of Bua)	NA	NA	NA	UVC surveys; observed in very low numbers	1998	Yeeting 1999
Fiji (Southern & eastern archipelago)	0.31	Varying levels	NA	6 fishing grounds surveyed, 5 sites per ground; surveys of > 15 cm TL; 5 fish observed in 162,000 m^2	1994	IUCN 2008 citing Jennings and Polunin 1996, 1997
Fiji (NW coast of Kadavu Island)	0	NA	NA	0 fish observed in 126,000 m^2	1995-1996	IUCN 2008 citing Simon Jennings, pers. comm.
Fiji (Lau)	0.7-4.78 (2.6)	Low	45-140	13 islands surveyed by UVC	1999-2000	Sadovy et al. 2003a and IUCN 2008 citing Nick K. Dulvy, pers. comm.
Fiji	0-8.4	From low to high	NA	7 separate locations	1994-2000	IUCN 2008

Table 3 *continued*

Sampled Location	Abundance	Fishing Pressure	Typical Size Range	Notes	Dates	Reference
Fiji	NA	NA	NA	22.5 mt annual catch (1994) to 3.5 mt (2003) = > 80% decline	1994-2003	IUCN 2008
French Polynesia	< 0.2	Heavy	NA	NA	1985-1997	Sadovy et al. 2003a citing Galzin et al. 1985
French Polynesia (Mataiva Atoll)	NA	NA	NA	Numbers in lagoon were generally low in all surveys; species absent in 1987	1981, 1983, 1985, 1987	IUCN 2008 citing Galzin et al. 1990
French Polynesia (Moorea)	NA	NA	NA	Fish observed on inner fringing reef, on top of barrier reef and 3 on outer reef over 15 survey months	1982-1983	IUCN 2008 citing Galzin et al. 1990
French Polynesia (Society Islands)	NA	NA	NA	Uncommon to rare in early 1970s; large fish rare following advent of spearfishing	Early 1970s	Sadovy et al. 2003a and IUCN 2008 citing Bagnis et al. 1972 and Galzin 1985
French Polynesia (Taiaro Atoll - Tuamotu Archipelago)	NA	None	92	Uncommon (1-2 fish in ~9 km^2 lagoon)	1972, 1992, 1994	Galzin et al. 1998
India (Kavaratti Atoll, Lakshadweep)	NA	NA	NA	Common; 50 fish observed in 38 days over 18 months via belt-transect surveys in depths 4-6 m	Jan 1991 - June 1992	Vijay Anand and Pillai 2002
Indonesia (Raja Ampat, N. Sulawesi, and Bali-Kangean)	0.40 (ranging from 0.04-0.86)	Low to high	NA	3 sites; included all size classes but mostly juveniles	2005	Colin 2006
Indonesia (Hoga Island in Wakatobi MNP)	50-220 (+/- 40-140) in coral; 50-120 (+/- 30-50) in seagrass	NA	NA	100 m^2 stationary point count surveys at 3 sites on intertidal to subtidal sea grass beds and fringing reefs; ubiquitous to all habitats and all tidal states ranging in depth from 0.7-2.3 m; fish size not defined but likely juveniles	April-May 2005	Unsworth et al. 2007

Table 3 *continued*

Sampled Location	Abundance	Fishing Pressure	Typical Size Range	Notes	Dates	Reference
Indonesia (Sangihe-Talaud Archipelago)	NA	NA	NA	5 fish in 80 hours over 67 sites; all but 1 were juveniles; 0-12 m depth range	2001	Halford and Russell 2002
Indonesia (Southeastern; Nusa Tenggara)	0.184	Heavy	NA	11 fish in 50 km^2; all ≤ minimum sexual maturation	April 2006	Sadovy 2006b
Madagascar (Andavadoaka)	NA	NA	NA	SPC surveys in reefs to depths < 18 m	April 2004-April 2005	Gillbrand et al. 2007
Malaysia (Eastern)	NA	NA	NA	3.3 mt (1995) to 0.2 mt (2003); > 10 fold decline; > 90% decline for the preferred size class of 0.3-3kg	1995 to 2003	IUCN 2008 citing Helen Hendry, pers. comm.
Malaysia (Pulau Layang Layang)	NA	NA	NA	350 fish 60-120 cm TL noted As of 2006, aggregation likely fished out	Late 1990s 2006	IUCN 2008 citing TRACC 2004 Colin and Sadovy de Mitcheson 2012
Malaysia (Sabah)	0.010	Heavy	NA	30 survey sites; only 2 sites had > 1 HW per km^2 surveyed; 99.91% decline since 1974; 2 reproductive sites identified	Since 1974	IUCN 2008 citing TRACC 2004
Malaysia (West of Sabah and Pulau Sipadan)	NA	NA	NA	70 fish recorded; protected by Navy and dive resorts	Late 1990s	IUCN 2008 citing TRACC 2004
Maldives	4-20	Low	60-100	NA	1996-1997	Sadovy et al. 2003a citing Sluka 2000
Mozambique (Quirimba Archipelago)	NA	NA	NA	Sampled artisanal fisheries catches from seine nets and fish traps in seagrass beds < 8 m	1996-1997	Gell and Whittington 2002
New Caledonia (Larégnère marine reserve)	9	None	NA	Survey area consisted of sea grass bed with associated coral heads	Nov 2004-July 2005	Chateau and Wantiez 2007 citing Chateau and Wantiez 2005

Table 3 *continued*

Sampled Location	Abundance	Fishing Pressure	Typical Size Range	Notes	Dates	Reference
New Caledonia (and the Tuamotu Archipelago in French Polynesia)	4.5 – barrier reefs; 1.4 – lagoon reefs; 0.3 – each for coastal reefs, lagoons & passes.	NA	NA	NA	Mar-Apr 2003	Gillett 2010
Niue	1.67	Low-med	80	NA	1985-1997	Sadovy et al. 2003a citing P. Labrosse
Palau	0.89-1.05	NA	60	37,071 (151,884 kg) estimated individual humphead wrasse in Palauan waters	May 2013	Friedlander and Koike 2013
Palau (SW Islands)	0-6 0-8.3	Low-med Med	35-185 24-170	NA NA	1999-2000 1999-2000	Sadovy et al. 2003a citing T.J. Donaldson, pers. comm. Sadovy et al. 2003a citing T.J. Donaldson, pers. comm.
Palau	2.0	NA Zero	NA	Outer reef slope densities; no change in density between 2006 and 2008. Considered "moderately abundant."	2006, 2008 2001-2007	P. Colin, pers. comm. citing Colin 2010 Palau Conservation Society report (unavailable) Colin 2010
Papua New Guinea (Kavieng)	5.6-9.2	Low	NA	NA	1997	Sadovy et al. 2003a citing J.H. Choat, pers. comm.

Table 3 *continued*

Sampled Location	Abundance	Fishing Pressure	Typical Size Range	Notes	Dates	Reference
Philippines (Palawan Province)	NA	NA	NA	Rare; all fish were juveniles < 15 cm (late 1990s, Calamianes Islands). Due to local depletion, fishery then moved south to main island of Palawan. ~70% of live reef food fish exports are from Taytay, Palawan. Catches are also now declining around Palawan, while demand for species escalates. Possession of species is prohibited under Section 97 of Republic Act 8550 of the Fisheries Code of 1998, with stiff fines. However, local contradictory regulations also manage the trade, and there is much illegal export.	Late 1990s	IUCN 2008 citing Werner and Allen 2000; WWF 2010; CNN 2011; GMA News 2012
Phoenix Islands	NA	Low	NA	Considered abundant	Pre-2003	Sadovy et al. 2003a citing G. Allen, unpublished data
Rowley Shoals	NA	Low	NA	Considered abundant	Pre-2003	Sadovy et al. 2003a citing J.H. Choat, pers. comm.
Seychelles	1.4-16	Low	NA	Considered relatively abundant	Pre-2003	Sadovy et al. 2003a citing J.H. Choat & L. Beckley, pers. comm.
Solomon Islands	0-4	Med	12-150		Pre-2003	Sadovy et al. 2003a citing T.J. Donaldson, pers. comm.
South China Seas	NA	NA	NA	Rare; formerly abundant (e.g., Pratas Reef, Paracel & Dangan Is). Small numbers brought in from Spratley Island	NA	IUCN 2008 citing multiple pers. comm.

Table 3 *continued*

Sampled Location	Abundance	Fishing Pressure	Typical Size Range	Notes	Dates	Reference
Taiwan	NA	NA	NA	Become uncommon in the Pescador Island and although occasionally taken around southern Taiwan (Orchid and Green Is), young fish rarely observed	NA	IUCN 2008 citing Sadovy and Cornish 2000 and K-T Shao, pers. comm.
Tanzania (Mafia Islands)	NA	Low	NA	Considered moderately common	NA	Sadovy et al. 2003a citing N.K. Dulvy, pers. comm.
Tonga (Tongatapu)	0-0.8	High	15-27	NA	NA	Sadovy et al. 2003a citing Secretariat of the Pacific Community (SPC) and the Institut de Recherche pour le Developpement (IRD)
Tonga (Ha'apai)	1.69	Med-high	8-110	NA	2001-2002	Sadovy et al. 2003a citing SPC and IRD
Tonga (Vavau)	3.17	Med	15-100	NA	2001-2002	Sadovy et al. 2003a citing SPC and IRD
Tuvalu	NA	NA	NA	Considered reasonably common, even > 100 cm TL	NA	Sadovy et al. 2003a citing R.E. Johannes, pers. comm.
U.S. - American Samoa	0.177	Zero	NA	NA	2002-2012	NMFS PIFSC CRED unpublished
U.S. - Marianas Archipelago	0.059	Zero-low	NA	NA	2003-2011	NMFS PIFSC CRED unpublished
U.S. - Palmyra Atoll	0.641	Zero	NA	NA	2001-2012	NMFS PIFSC CRED unpublished
U.S. - Wake Atoll	1.101	Zero	NA	NA	2005-2011	NMFS PIFSC CRED unpublished
U.S. - Wake Atoll	13-27	Zero	Large	Species is abundant, especially the juveniles (< 30 cm TL), and particularly between 5-30 m	NA	Sadovy et al. 2003a and IUCN 2008 citing P.S. Lobel, pers. comm., and Lobel and Lobel 2000

Multiple factors likely influence fish density and biomass. In some areas, abundance of humphead wrasse is low to non-existent, even when fisheries exploitation is known to be low or non-existent. As previously mentioned, at Taiara Atoll (Tuamotu Archipelago, French Polynesia), fish surveys were conducted in 1972, 1992, and 1994, and despite zero fishing pressure and high fish diversity, humphead wrasse abundance remained low with 1-2 fish (92 cm TL) observed in a 9 km^2 lagoon (Galzin et al. 1998). In the Mariana Archipelago, towed-diver surveys were conducted from 2003-2011 along the 10-15 m isobaths to survey large (> 50 cm TL) humphead wrasse. In the three northernmost islands of the Marianas Archipelago (Uracus, Maug, and Asuncion), which are uninhabited and are a part of the Marianas Trench Marine National Monument where commercial fishing is prohibited and recreational or subsistence fishing is very rare given the distance from most of the inhabited areas of the island chain, humphead wrasse were not observed. However, in the southern inhabited part of the chain, large humphead wrasse are present with densities of 0.023 (Tinian), 0.055 (Guam), 0.059 (Saipan), and 0.365 (Rota) individuals per 10,000 m^2 (Brainard et al. 2012; NMFS PIFSC CRED unpublished). One author suggests these differences might be attributed to lack of suitable juvenile habitat for humphead wrasse at uninhabited islands of the Mariana Archipelago (Tupper 2007).

As previously mentioned, fish abundance and biomass vary by region, habitat type, percent of substrate cover, and level of fisheries exploitation (Sadovy et al. (2003a) (Figure 9). In particular, in New Caledonia and Tuamotu Archipelago (French Polynesia), the abundance of humphead wrasse increased with increased hard coral cover and was highest around barrier reefs and at unfished areas. The smallest fish were observed in areas with high live coral cover, and the largest individuals in places where coral cover was low. The analysis of fishing impacts attempted to account for habitat effects by restricting analysis to data from habitats typical for the species. The fishing index was subjectively determined by interviewing each principle investigator (Sadovy et al. 2003a). The subjectivity of the fishing index and differences in depth range, habitats, and survey methods across surveys could have important unquantified effects resulting in uncertainty of this analysis.

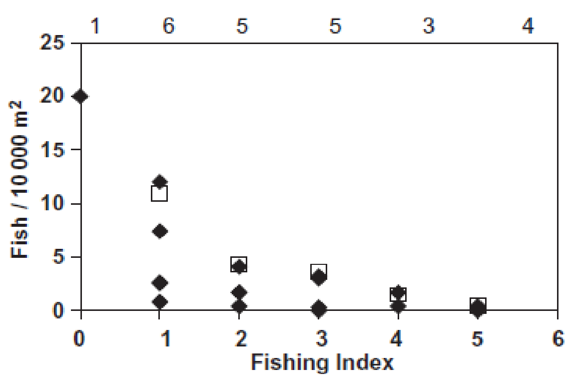

Figure 9.--Densities of *C. undulatus* determined from underwater visual census surveys observed at 24 different locations around the Pacific (e.g., Australia, 7 sites in Fiji, French Polynesia, Maldives, 5 sites in New Caledonia, Niue, 2 sites in Palau, Papua New Guinea, Solomon Islands, 3 sites in Tonga, and Wake Atoll) from pre-2003. For fishing pressure, 0 = none; 1 = low; 5 = high. The boxes in this figure represent the median values when a range was given. Methods were not standardized across studies (Source: Sadovy et al. 2003a).

3.7. Abundance within the United States Pacific Island Areas

NMFS Pacific RAMP surveys of reef fish were conducted at 40 U.S. Pacific Islands from 2000 to 2009 (Zgliczynski et al. 2013; unpublished data are now available through 2012 [NMFS PIFSC CRED unpublished]). Of the 40 islands and reefs included in this study, 15 islands were classified as inhabited and 25 as uninhabited. Underwater survey techniques used to estimate the density of diurnally active reef fishes included towed-diver surveys and belt transect methodologies in forereef areas in depths less than 30 m with a majority of surveys conducted at depths of 12-15 m (notably much shallower than the humphead wrasse's range of up to 100 m depth and beyond). Most data for humphead wrasse, however, is from the towed-diver surveys, which involved towing a diver behind a boat and counting all fishes > 50 cm TL (i.e., adult/mature fish) in a strip 10 m-wide centered on the diver. Each survey lasted ~50 minutes and covered an average of 2.2 km linear distance. Some presence data does exist for smaller size classes, but it has not been consistently gathered (NMFS PIFSC CRED unpublished).

As part of the NMFS Pacific RAMP surveys, NMFS conducted towed-diver surveys along forereef habitats during the Marianas Archipelago Reef Assessment and Monitoring Program (MARAMP) cruises in 2003, 2005, and 2007 (Brainard et al. 2012; unpublished data are now available through 2012 (NMFS PIFSC CRED unpublished)) and compared results between islands across the Marianas Archipelago. MARAMP surveys were conducted around Guam and 3 adjacent offshore banks (11-mile Reef, Santa Rosa Reef, and Galvez Bank), and around 13 islands (Rota, Aguijan, Tinian, Saipan, Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Farallon de Pajaros), 5 offshore banks (Tatsumi Reef, Esmeralda Bank, Marpi Bank, Zealandia Bank, and Supply Reef), and 3 remote reefs (Pathfinder Reef, Arakane Reef, and Stingray Shoal) on the West Mariana Ridge in the CNMI. Quantitative information from these NMFS surveys, along with data from other sources, is summarized in the following paragraphs (see also Figures 10, 11, and 12, and Tables 4-9).

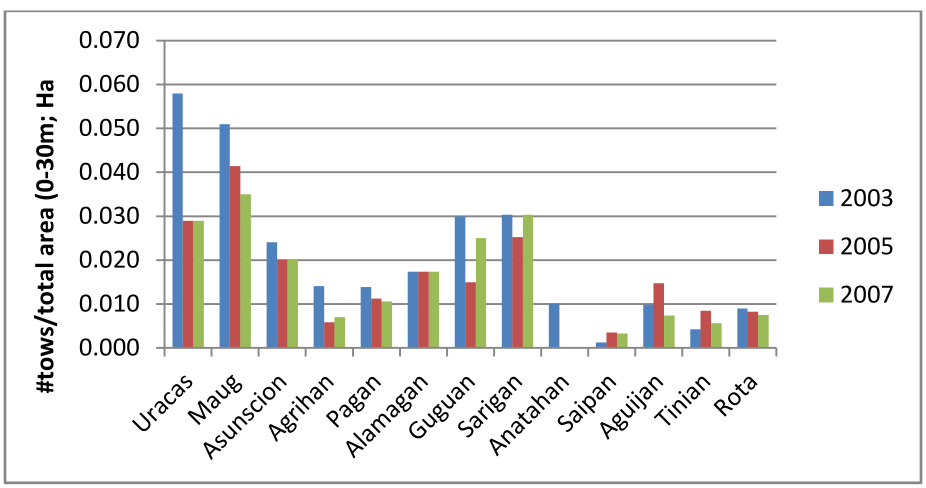

Figure 10.--Number of towed-diver surveys (50 minute, 2 km length, 10 m width for fish ≥50 cm) per area hardbottom (0-30 m) over CNMI islands sampled by NMFS PIFSC CRED in 2003, 2005, and 2007. Note FDM not included. (Sources: Williams 2010; Brainard et al. 2012)

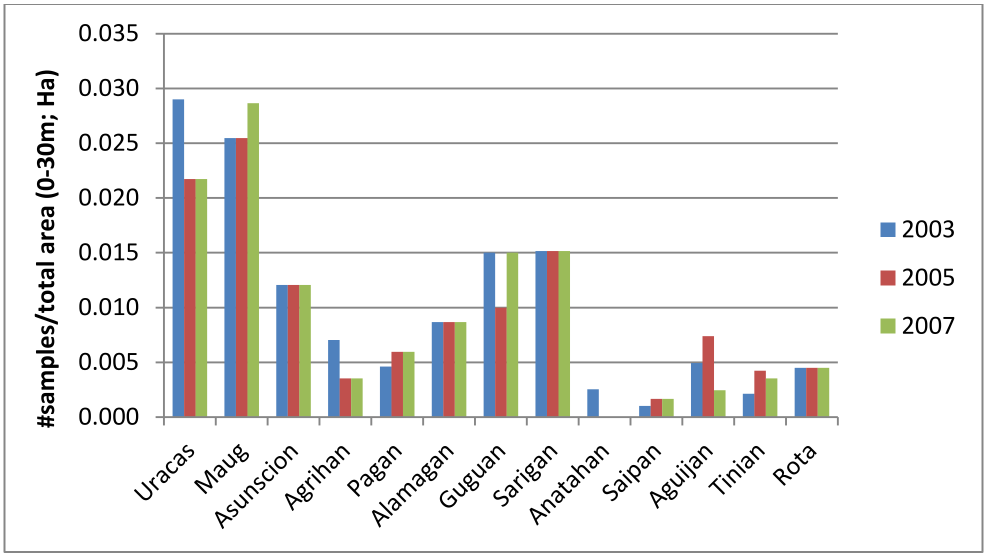

Figure 11.--Number of rapid ecological assessment samples (25m x 4m dual observer transects) per area hardbottom (0-30 m) over CNMI islands sampled in 2003, 2005, and 2007. Note FDM not included. (Sources: Williams 2010; Brainard et al. 2012)

Survey data show that while species density is relatively comparable or greater in some U.S. areas (e.g., Wake Atoll and Palmyra Atoll) compared to other international locales, there are a number of locations (e.g., Australia, Fiji, some sites in Indonesia, Maldives, New Caledonia, Papua New Guinea, Seychelles) that have an even greater abundance (see Table 3). It is important to note, however, that without consistent sampling methodology between survey efforts in different localities, which each have their biases, these comparisons remain uncertain, and a careful comparison between the methods in all areas is not available. NMFS PIFSC CRED RAMP towed-diver surveys only record species > 50 cm TL, meaning that smaller juveniles are not recorded. However, in other CRED diver surveys covering much less area, but recording all sizes of fish, only a small number of humphead wrasse < 50 cm were observed. It is also important to note that only a very small portion of available habitat in certain countries have been surveyed, which adds to the complexity of comparing abundance data across countries. Effort information from the Marianas Archipelago CRED RAMP for towed-diver and dual observer transect surveys for 2003, 2005, and 2007 are depicted in Figures 10 and 11. Greater survey effort was conducted in the Northern Islands of the CNMI overall relative to the more populated southern islands. Composition data of observed large fish from towed-diver surveys (Figure 12), suggests a generally greater abundance of humphead wrasse from north to south in the CNMI.

Humphead wrasse may be even more abundant in these U.S. Pacific Islands than estimated. This is based on anecdotal reports that assert that: A) more mature and larger *C. undulatus* have sought deeper waters over the years to seek refuge from spear fishers (American Samoa Department of Marine and Wildlife Resources 2013); B) there is a 40% chance of a juvenile wrasse within an observer's field of view going undetected (Western Pacific Regional Fishery Management Council 2013; Sabater et al. 2009); C) large humphead wrasse are known to shelter for long periods in reef caves and overhangs, and though this typically occurs at night, it also occurs in spearfishing areas so the species may not be readily observed, thereby fostering a belief of a population decline or even extirpation (Western Pacific Regional Fishery Management Council 2013); D) the NMFS towed-diver surveys did not extend to the maximum depth range of the species (Guam Fishermen's Cooperative Association 2013); E) harvest effort is on the decline as old fishers will not likely be replaced by younger fishers (CNMI 2010; Guam Fishermen's Cooperative Association 2013); and F) humphead wrasse have reportedly been observed more frequently with the establishment of marine protected areas, which support all life stages from juveniles to adults (Guam Department of Agriculture 2013).

The U.S. Territories and PRIAs have taken steps to protect reef fish species such as the humphead wrasse (see Tables 9 and 10). In addition to marine protected areas/no-take areas in each of the Territories and PRIAs, American Samoa and the PRIAs ban the harvest of humphead wrasse; American Samoa, the PRIAs, and CNMI ban SCUBA-assisted spearfishing (Guam has introduced but not yet passed a legislative bill to ban this as well); and all Territories and PRIAs ban destructive fishing practices. Additionally, Federal annual catch limits have been established specifically for the species and are not to exceed 5% of the estimated stock biomass (see Section

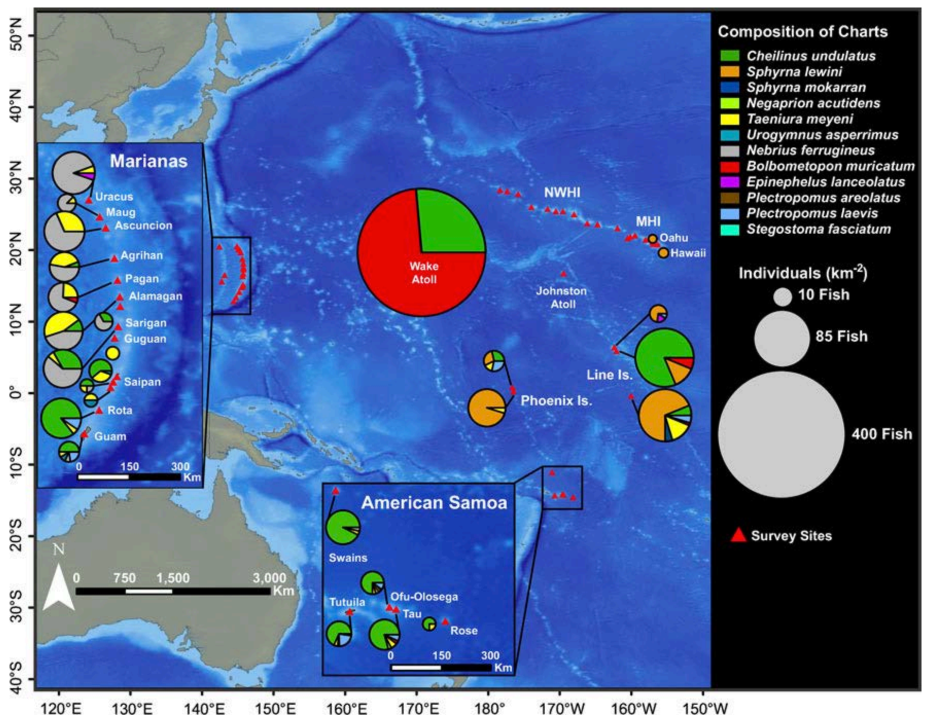

Figure 12.--Chart of the 40 U.S. Pacific Islands surveyed as part of the NMFS Pacific RAMP. Figure identifies the total mean density of IUCN Red-listed species facing the greatest threat of extinction, including the humphead wrasse. Data are based on towed-diver surveys conducted from 2000 to 2009 in upper forereef slope at depths < 30 m with a majority of surveys conducted at depths of 12-15 m. Each survey was 50 minutes and covered ~2.2 km of linear habitat (by 10 m wide). Pie diagrams indicate mean densities of fishes, with green representing humphead wrasse (Zgliczynski et al. 2013). (Note that the size of individual pies is proportional to the number of individuals ≥ 50 cm TL observed per km^2 vs. 10,000 m^2 as discussed throughout this document.)

5.4.1). While there is relatively little empirical data on the effectiveness of these measures, harvest records for Guam and CNMI indicate that the species is not directly targeted as it is of lesser value among reef fish species. In Guam, the species ranks 20 out of 29 for reef and bottom fish based on 5-year average price (Guam Fishermen's Cooperative Association 2013).

3.7.1. Marianas Archipelago

The Marianas Archipelago, comprising the 14 islands of the CNMI and Guam, is the U.S. jurisdiction closest to the Indo-West Pacific global center of marine biodiversity. The total mean abundance of *C. undulatus* ≥ 50 cm TL (via towed-diver surveys in ~12-15 m depth) is reportedly higher in the southern (inhabited) islands compared to the northern (uninhabited) islands of the Marianas Archipelago. In three MARAMP survey years, NMFS recorded a total mean abundance of 0.109 vs. 0.022 individuals/10,000 m^2 (i.e., 48 total sightings in the southern islands vs. 7 total sightings in the northern islands [NMFS PIFSC 2010; CRMO 2011; Zgliczynski et al. 2013]). They found significantly greater abundance at inhabited islands compared to uninhabited islands within the archipelago as previously noted. (Note that Island of Farallon de Medinilla (FDM) is leased by the Department of Defense for water-based and aerial operations training. The waters surrounding FDM provide limited access to non-DOD staff and the MARAMP has not been able to conduct surveys to quantify the incidence of *C. undulatus*, although the species has been observed there by DOD contractors and local CNMI Agency staff.) Overall, Rota Island in the CNMI had the greatest abundance of humphead wrasse with approximately 0.400 individuals/10,000 m^2 (Brainard et al. 2012; Zgliczynski et al. 2013; NMFS PIFSC CRED unpublished) (Table 4).

In addition to Pacific RAMP surveys, the CNMI Coastal Resources Management Office (CNMI CRMO) conducted quantitative and qualitative assessments of the humphead wrasse's abundance and distribution on outer reefs using the results of 67 towed-diver surveys (Saipan = 26; Rota = 21; Tinian = 15; Aguijuan = 5) from 2008 to 2010 (0-20 m depth, for 20 minutes, with a tow speed of ~3 knots). Though overall numbers were lower than what was recorded by NMFS (i.e., 48 observed in the southern islands by NMFS PIFSC CRED vs. 27 total individuals observed by CNMI CRMO [NMFS PIFSC 2010; CRMO 2011]; differences perhaps due to different methodologies), the CNMI CRMO considered the species to be widely distributed along forereef habitats. Both juveniles and adults were present around Saipan (8 adult individuals), Tinian (2 adult individuals), Rota (17 juveniles individuals), and Aguijan (0 individuals). Saipan lagoon was also surveyed (150 sampling points; at each point four 50 m x 10 m transects were surveyed), which consists of coral/rubble and *Acropora* spp. habitat. This area was noted as an important nursery ground with 27 juvenile (< 30 cm TL) humphead wrasse observed during surveys (CRMO 2010; CRMO 2011).

CNMI CRMO (2010) also reported that video surveys conducted by the University of Guam identified deeper reefs (30-90 m) as potentially important habitat for larger adult humphead wrasse, though none was seen during the surveys. When NOAA Fisheries PIFSC CRED conducted deeper (> 30 m) surveys using a Towed Optical Assessment Device (TOAD) camera around U.S. Pacific Islands (~2002-2008), no *C. undulatus* were detected, although potential habitat for the species was identified. However, it is likely that some humphead wrasses were missed due to the angle, narrow field of view, and imposing video lights (J. Rooney, pers. comm.).

A review of fisheries literature as a qualitative assessment for the species proved to be of limited value, as most publications do not go beyond the mere "presence" of the species in the Marianas. According to datasets mined by CRMO, CNMI's Marine Monitoring Team, University of Guam, NMFS, and FWS, the number of humphead wrasse from surveys is "low" (though "low" was not defined) (CRMO 2010).

Additional qualitative information on the humphead wrasse abundance in the CNMI is also available. From 2008 to 2010, 50 fishermen were interviewed to provide local perspective of the presence/absence of the species (CRMO 2010). Observations support the occurrence of spawning aggregations near the points of peninsula-like coastal formations and possibly, near channel mouths, though timing of aggregations is unclear. According to the majority of respondents, locally the species appears to be in decline compared to previous decades (CRMO 2010). In a complementary fishing interview conducted by NMFS Pacific Islands Regional Office that targeted 78 fishermen over the age of 40, a majority of these respondents also viewed the species to be in decline from historical levels (CRMO 2010). Experienced, elder fishermen attribute the perceived decline in abundance to the introduction of SCUBA fishing, especially at night beginning in the 1970s, though commercial fishing and increased fishing pressure were also cited as reasons for possible decline (CRMO 2011).

A volunteer environmental monitoring program (i.e., SCUBA diving operator and their clientele) run by the CNMI CRMO from 2006 to 2009 reported observations of humphead wrasse while scuba diving in Rota near Taipingot Peninsula (survey method not defined, though method was likely free swim). It is not uncommon for humphead wrasse to be observed at popular dive sites since fishing usually does not occur in the area and thus the species is typically less wary of humans. The dive operator and clientele reported observing fish ranging from an estimated 30 to 152 cm TL, with fish in the estimated size class 60-120 cm TL observed most frequently. Based on size, it was estimated that large males (~120 to 150 cm TL) accompanied one or more smaller females (30 to 90 cm TL). One of the largest aggregations observed had mixed sizes with eight fish in the 60 to 90 cm TL range and four in the 30 to 60 cm range (CRMO 2011).

Lastly, there exists other abundance information for the humphead wrasse in the CNMI, including abundance estimates obtained from long-term surveys by the CNMI Division of Fish and Wildlife (DFW). The stationary point count surveys for humphead wrasse were conducted by DFW from 2004-2008 (CNMI DFW 2013). On Rota, estimated abundance ranged from 0.86 to 1.27/10,000 m^2. Estimated size range of humphead wrasse observed in survey samples ranged from 40-150 cm TL, and outside of the survey area (i.e., observed when off survey effort or beyond the sampled survey area), the species had an estimated range from 50-180 cm TL. On Saipan, abundance ranged from 0.00 to 2.65/10,000 m^2, with estimated sizes ranging from 24-45 cm TL, and outside of the survey area, the species ranged from 45-120 cm TL. Data beyond 2008 have yet to be analyzed, as well as data from belt transects (M. Trianni, pers. comm.). These results, although unpublished, further indicate that the humphead wrasse is uncommon in the CNMI (CNMI DFW 2013).

Table 4.--Abundance of large (≥ 50 cm TL) humphead wrasse observed per 10,000 m^2 from towed-diver surveys of fore reef habitats (10-15 m depth) conducted in the Marianas Archipelago during NMFS MARAMP in 2003, 2005, 2007, 2009, and 2011. Each survey lasted ~50 minutes and covered ~2.2 km linear distance (by 10 m wide). Values in parentheses indicate standard error (± 1 SE) of the mean. (Note that surveys have not been conducted at the Island of Farallon de Medinilla (FDM) and the MARAMP has not been able to conduct surveys to quantify the incidence of *C. undulatus*, although Department of Defense contractors and local CNMI Division of Fish and Wildlife staff have observed the species there.) (Source: NMFS PIFSC CRED unpublished)

Marianas Archipelago Island	Island average - all years	2003	2005	2007	2009	2011
Farallon de Pajaros	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Maug	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Asuncion	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Agrihan	0.08	0.038 (0.038)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Pagan	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Alamagan	0.082	0.0 (0.0)	0.212 (0.212)	0.0 (0.0)	0.0 (0.0)	0.199 (0.199)
Guguan	0.048	0.0 (0.0)	0.0 (0.0)	0.099 (0.099)	0.0 (0.0)	0.143 (0.143)
Sarigan	0.125	0.0 (0.0)	0.0 (0.0)	0.175 (0.175)	0.318 (0.203)	0.131 (0.131)
Saipan	0.059	0.0 (0.0)	0.079 (0.079)	0.123 (0.075)	0.095 (0.053)	0.0 (0.0)
Tinian	0.023	0.0 (0.0)	0.07 (0.047)	0.0 (0.0)	0.0 (0.0)	0.046 (0.046)
Aguijan	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Rota	0.365	0.469 (0.244)	0.558 (0.257)	0.232 (0.111)	0.348 (0.133)	0.218 (0.098)
Guam	0.055	0.037 (0.026)	0.049 (0.035)	0.065 (0.047)	0.073 (0.041)	0.053 (0.039)
AVERAGE/MEAN	**0.059 individuals /10,000 m^2**	0.042	0.074	0.053	0.064	0.061

3.7.2. American Samoa

Per the NMFS Pacific RAMP surveys of fish > 50 cm TL from towed-diver surveys of fore reef habitats (10-15 m depth) conducted in American Samoa from 2002 to 2009, differences in mean densities were evaluated between inhabited and uninhabited islands in American Samoa. No significant difference was observed between inhabited and uninhabited islands (Zgliczynski et al. 2013). Though observed at all of the islands in American Samoa, the greatest abundance of the species was observed at Swains Island at 0.290 individuals/10,000 m^2 (Zgliczynski et al. 2013). New towed-diver survey data from NMFS through 2012 recorded humphead wrasse mean abundance at Swains Island at 0.383/10,000 m^2 (NMFS PIFSC CRED unpublished) (Table 5).

The American Samoa Department of Marine and Wildlife Resources (DMWR) anecdotally report that many humphead wrasse juveniles have been observed in shallow reefs (1 to 2 m depth) typically around sand and coral patches. Adults have been recorded in deeper waters, which have reportedly become a refuge for the species (American Samoa DMWR 2013). Three years of creel surveys (methods and dates not provided) have only reported two juveniles and zero adults in the catch records (American Samoa DMWR 2013). This may have to do with take of the species prohibited since 2012 (American Samoa Executive Order 002-2012) and SCUBA spearfishing banned since 2001.

Table 5.--Abundance of large (≥ 50 cm TL) humphead wrasse observed per 10,000 m^2 from towed-diver surveys of fore reef habitats (10-15 m depth) conducted in American Samoa during NMFS ASRAMP in 2002, 2004, 2006, 2008, 2010, and 2012. Each survey lasted ~50 minutes and covered an average of 2.2 km linear distance (by 10 m wide).Values in parentheses indicate standard error (± 1 SE) of the mean. (Source: NMFS PIFSC CRED unpublished)

American Samoa Island	Island average - all years	2002	2004	2006	2008	2010	2012
Ofu & Olosega	0.086	0.155 (0.099)	0.083 (0.045)	0.111 (0.050)	0.093 (0.050)	0.033 (0.033)	0.044 (0.044)
Rose	0.075	0.068 (0.046)	0.029	-	0.086 (0.046)	0.206 (0.145)	0.062 (0.062)
Swains	0.383	0.145 (0.106)	0.309 (0.130)	0.508 (0.167)	0.194 (0.117)	0.888 (0.276)	0.250 (0.0139)
Tau	0.182	0.094 (0.094)	0.198 (0.105)	0.253 (0.080)	0.243 (0.077)	0.099 (0.054)	0.207 (0.097)
Tutuila	0.161	0.195 (0.100)	0.120 (0.060)	0.104 (0.035)	0.121 (0.041)	0.156 (0.043)	0.267 (0.102)
AVERAGE /MEAN	**0.177 individuals /10,000 m^2**	0.131	0.148	0.195	0.147	0.277	0.166

3.7.3. Pacific Remote Island Areas

The NMFS Pacific RAMP surveys confirmed that the PRIAs have the greatest abundance of the species (Zgliczynski et al. 2013; NMFS PIFSC CRED unpublished) (Table 6). Within the PRIAs, the greatest abundance of the species was recorded at Wake Atoll, a Marine National Monument and National Wildlife Refuge managed and fully protected by the U.S. Department of Interior. According to the literature, the species at Wake is reportedly "abundant," especially the juveniles (< 30 cm TL) in waters 5 to 30 m deep (Sadovy et al. 2003a; Lobel and Lobel 2000; Lobel and Lobel 2004; Zgliczynski et al. 2013). Abundance at Wake (likely of juveniles) is reportedly 13-27 fish/10,000 m^2 (Sadovy et al. 2003a and IUCN 2008 citing Lobel and Lobel 2000 and P.S. Lobel, pers. comm.). More recent abundance data (of large ≥ 50 cm TL) humphead wrasse at Wake Atoll, however, averages 1.101 individuals observed/10,000 m^2 (Zgliczynski et al. 2013; NMFS PIFSC unpublished) (Table 7). While no information is reported on the survey that claims that abundance at Wake Atoll is 13-27 fish/10,000 m^2, the discrepancy of this abundance data vs. the newer abundance data of 1.101 individuals observed/10,000 m^2 may be due to surveying juveniles vs. adults, or differences in survey methods and times of years. The order of magnitude difference is significant though, especially since there is no fishing for the species at Wake Atoll.

Palmyra Atoll, also in the PRIAs, had the second highest abundance of large (≥ 50 cm TL) humphead wrasse with an average of 0.641 individuals observed/10,000 m^2 (NMFS PIFSC CRED unpublished) (Table 6). Fishing for the species in both Wake Atoll and Palmyra Atoll has been and continues to be banned.

Table 6.--Abundance of large (≥ 50 cm TL) humphead wrasse observed per 10,000 m^2 from towed-diver surveys of fore reef habitats (10-15 m depth) conducted in the PRIAs during NMFS RAMP in 2001, 2002, 2004, 2006, 2008, 2010, and 2012. Each survey lasted ~50 minutes and covered an average of 2.2 km linear distance (by 10 m wide). Values in parentheses indicate standard error (± 1 SE) of the mean. (Source: NMFS PIFSC CRED unpublished)

PRIA - Line and Phoenix Islands	Island average - all years	2001	2002	2004	2006	2008	2010	2012
Baker	0.008	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.056 (0.056)
Howland	0.043	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.155 (0.155)	0.0 (0.0)	0.147 (0.077)	0.0 (0.0)
Jarvis	0.094	0.112 (0.112)	0.0 (0.0)	0.0 (0.0)	0.035 (0.035)	0.19 (0.19)	0.410 (0.242)	0.086 (0.086)
Kingman	0.0	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Palmyra	0.641	0.644 (0.420)	0.982 (0.310)	0.612 (0.160)	0.316 (0.114)	0.839 (0.289)	0.383 (0.102)	0.709 (0.273)
AVERAGE/ MEAN	**0.157 individuals /10,000 m^2**	0.151	0.196	0.122	0.101	0.172	0.188	0.170

Table 7.--Abundance of large (≥ 50 cm TL) humphead wrasse observed per 10,000 m^2 from towed-diver surveys of fore reef habitats (10-15 m depth) conducted at Wake Atoll during surveys from NOAA RAMP in 2005, 2007, 2009, and 2011. Values in parentheses indicate standard error (± 1 SE) of the mean. (Source: NMFS PIFSC CRED unpublished)

PRIA - Wake	Island average - all years	2005	2007	2009	2011
Wake Atoll	1.101	1.980 (0.342)	0.804 (0.133)	0.758 (0.188)	0.862 (0.276)

4.0. DESCRIPTION OF THE FISHERIES

The humphead wrasse is occasionally and/or opportunistically consumed locally in small artisanal/traditional fisheries, while a small proportion is captured for the aquarium trade. The fishery with the highest catch, however, is the (mainly international) commercial live reef food fish trade (LRFFT), which includes capture for direct export as well as capture for mariculture (grow-out) to a larger size before direct export (see Figure 13; though this figure only depicts info for Indonesia, this pattern holds true for other countries in the LRFFT as well (Sadovy et al. 2003a; Gillett 2010)).

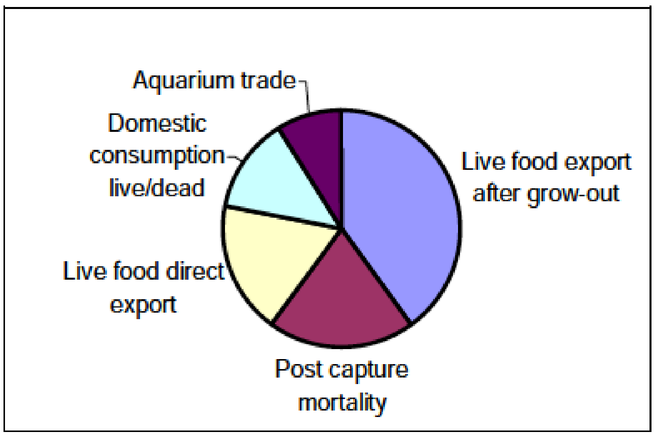

Figure 13.--The fate of captured humphead wrasse in Indonesia. The chart shows relative amounts by weight. (Source: Gillett 2010 citing Directorate General of Forest Protection and Nature Conservation 2006.)

4.1. Artisanal Fisheries and Traditional Use

Other than activities oriented to the LRFFT, there are few "directed" fisheries for the humphead wrasse due to its natural rarity and the inherent difficulty of capturing the fish (Gillett 2010). In most countries where the fish occurs, most of the catch of this species is for domestic use. While the target size is often indiscriminate, the species is typically caught via spearfishing (particularly at night) while free diving or using hookah/SCUBA diving, or via hook-and-line (Tables 8 and 9). Although some information has been summarized here, there may be other artisanal/traditional fisheries for which data is lacking. Therefore, it is unknown if or to what extent fisheries may be impacting the humphead wrasse populations.

For the U.S. fishery in Guam, the only useful commercial and recreational fishery information is provided in Section 3.4 and Table 9. Although a small fishery with traditional elements, it makes use of SCUBA (Lindfield et al. 2014). The fishery averages several thousand pounds per year and has been sustained without clear trend from the early 1990s through 2011.

For the U.S. fishery in Guam, the only useful commercial and recreational fishery information is provided in Section 3.4 and Table 11. Although a small fishery with traditional elements, the method commonly employs SCUBA (Lindfield et al. 2014). The fishery averages several thousand pounds per year and has been sustained without clear trend from the early 1990s through 2011.

The humphead wrasse has some cultural and traditional value as a food fish in a number of countries (K. Rhodes 2006, pers. comm.). Sadovy et al. (2003a; 2003b) cite to a number of personal communications that portray how the humphead wrasse has, or had, strong cultural significance where commemorative occasions are marked by consumption of this species in the western Pacific, notably Palau, Guam, Fiji, Cook Islands, Yap, Pohnpei, and parts of Papua New Guinea.

Table 8.--International fishing activities summarized for the humphead wrasse. (Source: from Gillett 2010 citing Sadovy et al. 2003a)

Country	Fishing activity
Australia Great Barrier Reef	Handline/1–3 hooks; taken for live trade, also fresh, frozen, fillet and whole for domestic use – few for public aquaria. Prize catch in spearfishing contests and for recreation. Exports of live fish were only permitted by air.
Fiji	Night spearfishing and poison (derris) widely used; considered difficult to catch using other means; in the past some export both live and chilled. One live fish operation exported fillets taken from humphead wrasse considered too large to export live, and about 4 tonnes live annually. Only two live reef fish exporters currently active. Since September 2004 there has been a ban on the commercial take, capture for sale, offer for sale, or possession of live or dead specimens of the humphead wrasse.
French Polynesia Society Islands	Spearfishing for domestic use, more recently involving taking larger fish from sleeping holes at night. No known export.
Guam	Night spearfishing on SCUBA. No known export.
Indonesia	The species is heavily sought for live export. Many fish caught live with cyanide; other methods not considered so efficient. Small fish heavily taken for mariculture grow-out (see Mariculture) by small trap, hook and line, net or cyanide. Mariculture (from grow-out) is now a common means of procuring live fish. Illegal fishing and corruption are associated with the trade. Export of live humphead wrasses by sea and air; larger fish by sea, those <2 kg often by air. Some fillets are also exported by air, according to the Agriculture, Fisheries and Conservation Department, The Government of the Hong Kong Special Administrative Region of the People's Republic of China, AFCD'S confiscations in China, Hong Kong SAR.
Japan	Unknown capture method. Some aquarium trade. No known export for food.
Kiribati, Christmas Island	The species is considered to be particularly vulnerable to fishing. Export has occurred sporadically, but no operations were functional in mid-2007.
Malaysia, Mainly Sabah	Humphead wrasse is a prime target for live export. Fish are taken by cyanide and hook and line, and frequently captured while juvenile and grown-out in cages to market size, especially in Kudat, Sabah. Much illegal fishing also takes place in southern Philippines waters with fish exported via Malaysia, mainly by air.
Marshall Islands	The species is sought for live export and transported by sea to China, Hong Kong SAR.
Mayotte Comoro Archipelago **and Madagascar**	Spearfishing and handlining of small numbers of humphead wrasse for local use. No known export.
New Caledonia	There is no known export of live humphead wrasse. Small fish (<40 cm TL) occasionally sold dead in Noumea markets, with larger fish sold as fillets (recognizable by the skin attached to fillet). Not common, taken by spear.
Palau	Taken by spear at night, since 1970s with torch and increasingly with SCUBA at night although use of SCUBA with spear is illegal. Long used for local customs, it was briefly exported live in the mid 1980s.
Papua New Guinea	The species is especially sought for live export, although there is some local use for customs. Small fish are grown-out in cages. Sometimes caught by using derris to stupefy fish which is then put in a copra sack at night. Fish exported by sea and air.
Philippines	The species is a prime export fish. Juveniles are commonly caught and grown-out in cages to market size in certain areas (e.g. Palawan). Cyanide is the fishing method reported for this species. Small fish taken dead in traps sold locally. Export of live fish is principally by air and all is illegal. Much reaches China, Hong Kong SAR via illegal trade through Malaysia.
Seychelles	Not traditionally taken but targeted briefly for export of live fish; shipments transported by sea.
Solomon Islands	This species is sought for live export with some domestic sale. In the Western Province, fish are taken with traditional traps that are baited and closed by hand when the fish enters and with hook and line or spear. Export by sea only, when permitted; no export operations were functional in mid-2007.
South China Sea	Small numbers taken in the past from China, Hong Kong SAR, Hainan Islands, and especially from offshore reefs (Pratas Reef, Paracel and Dangan Islands), and Pescador Islands of Taiwan, largely by spear or cyanide.
Tuvalu	No known export. Occasionally taken by spear, or by hook and line baited with land crabs. Not a prized fish.

Table 9.--Fishing activities in U.S. territories summarized for the humphead wrasse.

American Samoa	Although a Federal annual catch limit of 5% of the total estimated stock biomass within American Samoa exists, fishing for humphead wrasse does not occur. The American Samoa Executive Order 002-2012 (enforced by Department of Marine and Wildlife Resources) strictly prohibits any interaction with the species (i.e., possess, sell, kill). SCUBA spearfishing was banned in 2001.
Commonwealth of the Northern Mariana Islands	Federal annual catch limits allow 5% of the estimated stock biomass to be landed and free dive spear fishing at night is the primary method by which humphead wrasses are landed in the CNMI. There have been no reported landings using hook and line. The species is not a target of local commercial fishermen as it does not command a greater price per pound, being taken incidentally to target species harvest. Historically, there has not been an aquarium trade or LRFFT for humphead wrasse in the CNMI.
Guam	Harvest records from 2007-2011 indicate that the species is not targeted as it is of lesser value among reef fish species (species ranks 20 out of 29 for reef and bottom fish based on 5-yr average price; species ranks 12 out of 17 for reef fish only). It is caught opportunistically via spear and consumed locally. With Federal annual catch limits allowing 5% of the estimated stock biomass of humphead wrasse to be landed, 5-year commercial landings for the species average 2,410 lbs/yr with an average price of $2.78/lb. The species is not commercially exported (Guam Fishermen's Cooperative Association, 2013).
PRIAs	No known fishing; fishing for the species is strictly prohibited within 12 nm of the following areas: Rose Atoll, Howland, Baker, and Jarvis Islands, Kingman Reef, Johnston Atoll, Wake Atoll, and Palmyra Atoll (78 FR 32996, June 3, 2013).

4.2. Commercial Fisheries

Commercially, the humphead wrasse is caught in low volume fisheries in different ways according to its size and whether it is needed alive or dead (Sadovy et al. 2003a). The species is sold for domestic consumption, exported for food for the LRFFT, exported for mariculture until the fish is large enough for consumption, or exported for aquaria.

Commercial fishing for humphead wrasse occurs via a number of methods. Fish traps typically use live or dead fish as bait whereas hook and line use crabs as bait, although the species is not easily taken with hook and line (Sadovy et al. 2003a). Spearfishing is also a popular method. Historically, commercial spearfishing began in Samoa in the late-1980s when a commercial SCUBA diving company began using the company's SCUBA gear for spearfishing during their free time. The popularity of SCUBA spearfishing grew over the years and spread to other countries (Gillett and Moy 2006). In Palau, Guam, Tahiti, Tonga, and Fiji where larger fish could be speared, SCUBA, hookah, and free divers often easily capture the species at night while the fish rests in caves and crevices (Bagnis et al. 1972; Johannes 1981; Thaman 1998; Sadovy et al. 2003a citing T. Pitlek and T.J.D., personal observation). Commercial fishers also use spear guns to target the species. Most commercial fishing for the species, however, is done using cyanide poisoning (CITES 2010b).

4.2.1. Live Reef Food Fish Trade

The live reef food fish trade, or LRFFT, is a highly lucrative industry that involves the capture of reef fish that are kept alive for sale and consumption. The top three exporters of humphead wrasse for the LRFFT are Indonesia, Malaysia, and the Philippines, respectively (Sadovy et al. 2003a; CITES 2010b; Sadovy de Mitcheson et al. 2010; Sadovy et al. 2011). The major importing countries for the species are China (into and through Hong Kong), Taiwan, and Singapore (Sadovy et al. 2003a). Hong Kong and mainland China are the major consumers and together accounted for c. 60% of the trade in the mid-1990s (Sadovy et al. 2003a; Fabinyi 2011).

For about three decades, the humphead wrasse has been a small but significant component of the commercial LRFFT as one of the highest-valued luxury food items (Sadovy et al. 2003a; Sadovy et al. 2003b; Gillett 2010). The heavy demand and high prices for the species in the LRFFT is fueled by their freshness and flavor since fish are selected live from restaurant aquariums only minutes before eating, as well as for their reputed virility-enhancing and overall health-promoting qualities (Erdmann and Pet-Soede 1997).

The history of the LRFFT, as summarized by Johannes and Riepen (1995), began centuries ago, as part of a still popular Chinese custom to keep fish alive until moments before they were cooked. Until recent decades, these fish were limited to fresh water and marine species caught in local waters as adults or as early or late-stage juveniles or sub-adults and raised in captivity to market size. Beginning in the late 1960s, a few marine species from more distant waters began to appear in Hong Kong's live fish markets. At first, most of these fish were imported as fingerlings and raised in net cages. This was the birth of marine fish farming in local waters. Chinese consumers maintained, however, that wild-caught adult fish looked and tasted significantly better than farmed ones. Full-size, wild-caught fish thus fetched higher prices. In 1975, two innovations were introduced: the use of cyanide to catch fish, and the shipping of the high value species by air. In 1984, a Hong Kong company began fishing for groupers and humphead wrasse in Palau, the nearest Pacific Island group and the first islands so-targeted. By 1989, Hong Kong companies were moving quickly into Indonesia. Live reef food fish fishing activities of Hong Kong companies expanded into new areas, including Papua New Guinea (1991), Australia (1993), Maldives (1993), and the Solomon Islands (1994). By 1994, fish stocks in some areas were showing signs of severe depletion.

Since the early 1990s, the LRFFT has expanded rapidly, placing heavy pressure on larger preferred reef fishes like the humphead wrasse (Sadovy et al. 2003a). In the early 2000s, it was number one on the “top ten most-wanted species” list published by the World Wildlife Fund for Nature, indicating high demand (Courchamp et al. 2006).

4.2.2. Mariculture

Mariculture involves either culturing (breeding) humphead wrasse by inducing adults to spawn and raising the larvae until desirable market size, or capturing wild juvenile humphead wrasse and growing them out until desirable market size. Multiple efforts for breeding the species have been met with little success (McGilvray and Chan 2003; K. Rhodes 2006, pers. comm.). Closed system (or hatchery) culture (e.g., no reliance on wild broodstock) appears to be particularly difficult because of small larval sizes, rare broodstock, and feeding regimen problems (Sadovy et al. 2003a citing M. Rimmer, pers. comm.). However, Slamet and Hutapea (2005) report that after numerous attempts to rear larvae, captive humphead wrasse broodfish were successfully spawned in Indonesia in 1998. Following many years of research on gonadal development, spawning, and larval rearing, in 2003 they produced the first hatchery production of this species with 120 juvenile humphead wrasses. Although there are two established mariculture facilities in Indonesia, neither has reportedly been successful in culturing and rearing humphead wrasse to adult size (Sadovy 2006a), and hatchery production is no longer a priority for the species (CITES 2010b; Sadovy et al. 2011).

5.0. ANALYSIS OF THE ESA SECTION 4(A)(1) FACTORS

The ESA requires NMFS to determine whether a species is endangered or threatened because of any of the factors specified in section 4(a)(1) of the ESA. The following provides information on the threats from each of these five factors as they relate to the status of the humphead wrasse. An analysis of the extent that each of these threats is appreciably reducing the fitness of the species or its habitat can be found in Part II: Assessment of Extinction Risk for the Humphead Wrasse section of this document.

5.1. (A) Present or Threatened Destruction, Modification or Curtailment of Habitat or Range

The humphead wrasse is widely distributed on coral reefs and inshore habitats throughout much of the tropical Indo-Pacific Ocean to depths up to 100 m and beyond. Habitat threats in these areas include destructive fishing practices, loss/modification of juvenile nursery areas, and loss/modification of adult habitat. Climate change and pollution, which may affect the quality of habitat, is discussed under the evaluation of Factor E: Other natural or manmade factors affecting the species' continued existence.

5.1.1. Destructive Fishing Practices

Destructive fishing practices including muro-ami fishing, blast fishing, and cyanide poisoning are used throughout much of the species' range. These fishing methods are indiscriminate in the destruction and modification to the humphead wrasse's primary habitat, which spans coral-rich areas of reefs, from lagoons to reef slopes, channels, and passes occurring over a broad geographic range.

Muro-ami fishing is a type of drive-in net fishing technique whereby a line of fishermen in the water use an encircling net together with pounding devices to smash coral in the area into small fragments in order to scare the fish out of their coral refuges. This type of fishing is reportedly widespread in the Philippines and elsewhere (Poh and Fanning 2012). While this type of fishing is not used to capture humphead wrasse, it does affect the species' habitat.

Blast fishing and cyanide poisoning are the reported “heavy weights” in destructive fishing practices (Poh and Fanning 2012). Blast fishing is used to source bait for hook-and-line fisheries as well as provide fish feed for the mariculture or grow-out of the juvenile humphead wrasse (Poh and Fanning 2012). This method has evolved from the use of dynamite to homemade kerosene and fertilizer bombs in beer bottles. With this method, schooling reef fish are located visually, after which the capture boat moves within close range and throws a lighted bomb into the middle of the school. After the bomb explodes, fishermen collect the stunned or killed fish using either free diving or hookah techniques. Although this type of fishing typically targets schooling reef fishes such as surgeonfish, rabbitfish, and snappers (Poh and Fanning 2012), humphead wrasse are also found in these areas. Habitat destruction from these types of fishing practices where the reef is reduced to rubble remains an issue for the species. In locations such as Malaysia, it is a main cause in the decline of the coral reef fisheries (Poh and Fanning 2012).

Cyanide poisoning is considered the easiest of the three methods. As the “gear” of choice for capturing live reef food fishes (Poh and Fanning 2012), especially humphead wrasse, its use is widespread. It has been suggested that more than 90% of all small humphead wrasse are caught by cyanide (CITES 2010b) because the species is difficult to catch efficiently and in large numbers via hook and line.

Unlike other forms of destructive fishing such as muro-ami and blast fishing, which are utilized largely for subsistence fisheries, cyanide fishing is driven mostly by the international commercial trade in live coral reef fishes (Bruckner 2001). Aquarium fish collectors typically use one or two 20 g cyanide tablets in a one-liter squirt bottle, while food-fish fishers use three to five 20 g cyanide tablets per liter (Rubec et al. 2000). Fishers squirt cyanide into coral formations to stun and collect their prey, using a crowbar to pry apart the coral heads to reach the fish that retreat into crevices (Barber and Pratt 1997). Cyanide affects oxygen uptake at the gills and slows the fish down, allowing the fisher to remove the fish by hand before the toxin kills it (Sadovy et al. 2007). Cyanide kills many non-target fish along with corals, sponges, and other reef invertebrates (Jones and Steven 1997; Yan 2011), and a large percentage of the fish that are captured die in transit (Rubec 1988). Cyanide is known to cause extensive collateral environmental damage (Johannes and Riepen 1995), and in areas where cyanide fishing has been practiced heavily, the reef is mostly dead, overgrown with algae, and has only very few animals still living on it (Pet and Pet-Soede 1999). Branching *Acropora* spp. corals are likely the most commonly poisoned corals because fish take refuge in their branches to avoid collectors (Cervino et al. 2003). These corals, which all size classes of humphead wrasse can be found living in and amongst, are the most susceptible to cyanide exposure. Many corals subject to experimental levels of cyanide similar to levels used by fishers exhibited some form of effect of cyanide exposure such as secreting excessive mucus, expelling zooxanthellae until bleaching, having reduced photosynthesis and calcification rates, and even mortality (Jones and Steven 1997; Cervino et al. 2003).

Despite many countries banning cyanide fishing, it still occurs in approximately 15 countries, many of which are major exporting nations in the coral reef wildlife trade (Bruckner and Roberts 2008). The high value of live reef fish drives the continued use of cyanide (Bryant et al. 1998) and more than a billion grams of cyanide have been used since the 1960s in the Philippines alone (Barber and Pratt 1997). Cyanide fishing has spread into remote locations and is of particular concern as these areas have been minimally impacted by other human threats (Johannes and Riepen 1995). As of 1998, there were an estimated 20,000 cyanide fishermen operating in the Indo-Pacific region (Barber and Pratt 1997).

Several types of cyanide fishing operations have been documented in Indonesia, including large-scale operations working mostly in remote and pristine areas, and small- and medium-scale operations working in more densely populated and exploited reef areas (Pet and Pet-Soede 1999). Although information is dated, large-scale operations are typically a month in duration and utilize a mothership outfitted with small skiffs and manned with crews of about 20 people. Once on site at the fishing ground, catches are transferred to floating cages or to concrete basins on shore before vessel or airfreight transport to Hong Kong. Medium-scale operations are typically three days in duration and employ a five-man crew using hookah gear. Small-scale operations consist of a single fisherman relying on a small canoe and free-diving methods for capturing fish. Both small- and medium-scale operations sell their fish from floating live fish cages (Pet and Pet-Soede 1999).

Despite the lucrative incentive to use cyanide, Barber and Pratt (1997) report that experience in the Philippines suggests that when cyanide fishermen are introduced to cyanide-free techniques for live-fish capture and ensured fair prices for their catch, they are willing and often eager to give up using the poison and talk about ways to ensure the long-term sustainability of their local reefs and fisheries. Development of reliable alternative sources of income strengthens these incentives, and strict government enforcement of anti-cyanide-fishing laws reinforces them (Barber and Pratt 1997).

In summary, though not all fishing for the species for the LRFFT occurs via destructive methods, where applicable destructive fishing practices are a threat that directly affect the habitat of all life stages of the humphead wrasse. Cyanide fishing is the primary commercial fishing method used to capture the humphead wrasse for the LRFFT, despite the fact that it is illegal in many countries (see Tables 12 and 13). Currently it is unknown how many fishermen continue to use cyanide in the Indo-Pacific region.

5.1.2. Loss of and/or Modification to Juvenile Nursery Areas

Sea grass beds, mangroves, turf algae, and fine-branching coral in shallow reef areas provide nursery habitat for post-settlement and juvenile humphead wrasse. Though information on impacts to sea grass beds and mangroves in the Indo-Pacific is lacking (Waycott et al. 2009), direct and indirect loss or modification to all nursery habitats can be attributed to a number of threats. Direct loss can result from direct harvest and stressors incurred from coastal development and engineering, sedimentation, degraded water quality, destructive fishing practices (such as cyanide, which prevents new coral recruits from successfully settling on the dead reefs [Pet and Pet-Soede 1999]), overfishing, aquaculture, anchor damage, and cutting of mangroves for firewood used to fuel open-fire cooking stoves. Indirect loss can occur from aquaculture and severe weather events including cyclones, large wave events, and tsunamis (discussed later). These threats have been documented in all of these habitats globally (Brouns 1994; Ruiz et al. 2001; Alongi 2002; Orth et al. 2006; Waycott et al. 2009). For example, one comprehensive global assessment found that sea grasses have been disappearing at a rate of 110 km^2 per year since 1980, with rates of decline accelerated from a median of 0.9% per year before 1940 to 7% per year since 1990 (Waycott et al. 2009). Approximately one-third of mangroves, which presently occupy about 181,000 km^2 of tropical and subtropical coastline, have been lost over the past 50 years (Alongi 2002). Sea grass beds and mangrove habitat play an important ecological role with numerous coral reef organisms utilizing the connectivity between these habitats at various stages in their life cycle (Unsworth et al. 2008). However, the magnitude of the direct and indirect threats to these habitats and others such as reefs is variable and unknown across the biogeographic range of the humphead wrasse, with possible impacts more severe in areas that are more densely populated by humans (Alongi 2002).

5.1.3. Loss of and/or Modification to Adult Habitat

In addition to destructive fishing practices that directly contribute to the loss or modification of habitat for all life stages of the humphead wrasse, other threats indirectly affect the humphead wrasse's habitat on coral reefs and other coastal ecosystems of the Indo-Pacific region. Indirect threats include unsustainable fishing practices that lead to alterations in fish communities; coastal development; runoff from industrial activities, mining, logging, fertilizers and pesticides; sedimentation; and effects from climate change (Pet and Pet-Soede 1999; Jackson et al. 2001; Hughes et al. 2003; Halpern et al. 2008; Pandolfi et al. 2011). The magnitude of these threats to habitats used by humphead wrasse may vary across the species' range, but how they may directly or indirectly impact the humphead wrasse are poorly understood. Impacts presumably appear to be more severe in areas that are more densely populated by humans and easier to reach, although remote areas may also be impacted. To date, efforts to examine the direct and indirect effects of human impacts to the demography of humphead wrasse are lacking.

5.2. (B) Overutilization for Commercial, Recreational, Scientific or Educational Purposes

Threats related to the overutilization of humphead wrasse stem from artisanal and commercial fisheries. The commercial fishery threats include the live reef food fish trade, harvest of juveniles for the marine aquarium trade, harvest of juveniles for mariculture, extirpation of spawning populations at aggregation sites, and illegal, unregulated and unreported fishing.

5.2.1. Artisanal Fisheries

As previously mentioned, other than for the LRFFT, there are few "directed" fisheries for the humphead wrasse due to its natural rarity and the inherent difficulty of capturing the fish (Gillett 2010). However, both targeted and opportunistic fishing for artisanal/subsistence purposes do occur throughout its range (Sadovy 2005; K. Rhodes 2006, pers. comm.). Spearfishing via free or SCUBA diving is the main artisanal fishing method for humphead wrasse and is typically conducted at night when the humphead wrasse is asleep in a crevice or cave on the reef. The main advantages of SCUBA spearfishing are the ability to access greater depths and increase bottom time, both of which increase a diver's ability to target high value species like the humphead wrasse. Spearfishing appears to be more widely used to target humphead wrasse for artisanal purposes compared to hook-and-line. As noted in section 4.1, there is little information available on the volume of artisanal/traditional fisheries catch, and the impact of these fisheries alone on humphead wrasse populations is unknown. However, in recognition of the decline of the humphead wrasse, night spearfishing has recently (i.e., since the start of the 21st century) been banned in certain countries/regions and has shown some success in addressing the issue of overharvest (Gillett and Moy 2006). For example, Fiji, American Samoa, and the CNMI have banned SCUBA-assisted spearfishing, and Fiji and the Solomon Islands have banned night free-dive spearfishing (Western Pacific Regional Fishery Management Council 2013). The inadequacies of most voluntary fishery-dependent data reporting in the U.S. Pacific Island Territories for determining the species composition of catch was addressed by NMFS Commercial Fisheries Biosampling Program starting in 2010. These efforts have provided much needed data pertaining to species targeted as well as length and weight data for each species. By comparing the size distributions catch data from Guam, where SCUBA allows divers to access greater depths compared to CNMI, where SCUBA is banned (Figure 14), indicates that the use of SCUBA provides better access to additional habitats and increases the catch of large adult fish. These data suggest that banning SCUBA spearfishing may provide depth refugia for adults.

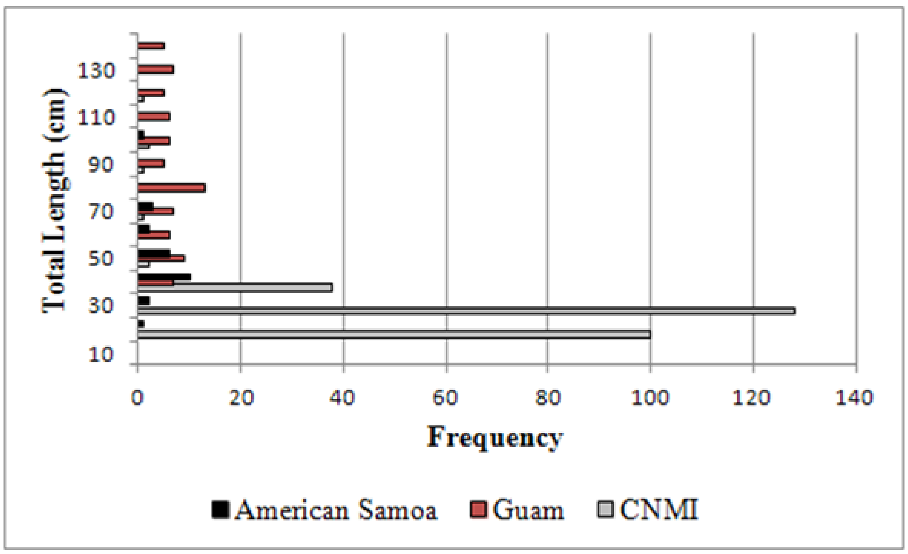

Figure 14.--Size-frequency data (number of fish by size) for the sampled catch of humphead wrasse (Source: NMFS Commercial Fisheries Biosampling Program in three U.S. Pacific Island Territories, 2009-2014, NMFS PIFSC).

A number of countries have also recently (i.e., 1990s and 2000s) regulated artisanal fishing for humphead wrasse. Regulations include: banned the taking of the species (i.e., Maldives, Palau); enacted minimum size limits for domestic consumption (e.g., Papua New Guinea and Samoa); constrained domestic fishing (e.g., Australia, Philippines, Samoa, and CNMI); regulated harvests (e.g., Indonesia); or created no-take marine protected areas (MPAs) (e.g., Chagos Marine Reserve, Kiribati's Phoenix Islands Protected Area, Palau, or within the U.S. Marine National Monuments) (Gillett 2010; Western Pacific Regional Fishery Management Council 2013). Having regulations and management measures in place for the humphead wrasse is only one aspect of fisheries management though. The success of these measures is highly dependent on enforcement. A lack of enforcement rather than a lack of regulation may be the key driver in promoting non-compliance and even IUU activities (Spait 2001; Poh and Fanning 2012). According to Gillett (2010), enforcement is considered challenging because it is difficult to keep low-income fishers from capturing an extremely valuable fish that is within their grasp. Enforcement at the commercial level may be more manageable, however, if measures are more easily enforced. For example, quotas at the point of export, attention to enforcement at the level of collectors/buyers/exporters, and sometimes, marine protected areas. Limiting the points of exports or modes of transport can also aid enforcement (Gillett 2010).

5.2.2. Commercial Fisheries

The literature and data overall suggest that the species cannot withstand anything other than light to moderate fishing pressure (Donaldson and Sadovy 2001; CITES 2004). The life history and ecology of this species make it more vulnerable than most other coral reef fish to overexploitation from commercial fisheries, as discussed below (NMFS PIFSC 2010; Muñoz and Zgliczynski 2011; Zgliczynski 2013).

5.2.2.1. Live Reef Food Fish Trade. As stated earlier, the top three exporters of humphead wrasse for the international LRFFT are Indonesia, Malaysia, and the Philippines; the major importing countries for the species are China (especially Hong Kong), Taiwan, and Singapore (Sadovy et al. 2003a; CITES 2010b; Sadovy de Mitcheson et al. 2010; Sadovy et al. 2011). Although stocks appear to be in poor condition wherever uncontrolled spearfishing occurs or has occurred (e.g., Madagascar, Tahiti, China, and islands of the South China Sea) and especially if compressed air (via SCUBA diving or hookah) is used to take fish from sleeping places at night, declines appeared to be particularly marked where a significant portion of the LRFFT occurs or has occurred (e.g., Indonesia, Malaysia, and Philippines) (Gillett 2010).

The international LRFFT is arguably the greatest threat to humphead wrasse in Southeast Asia or wherever it is fished for this trade (Sadovy et al. 2003a; Gillett 2010; Sadovy 2010). It is because of this trade that this species was listed on CITES Appendix II. Trade is almost exclusively destined for Hong Kong and mainland China (Sadovy et al. 2003a; Gillett 2010). Trade is conducted via sea and air routes. Trade by sea is far harder to monitor than that by air and much of this trade in the species may go entirely undocumented (Sadovy unpublished).

Researchers focusing efforts to study humphead wrasse have identified several key issues with the LRFFT. First, the removal of late stage juveniles and small adults from the wild before they have had a chance to reproduce, leading to growth overfishing. Second, unsustainable fishing practices have depleted stocks at fisheries grounds close to human population centers and have led to fishers moving to new fishing grounds to meet the demand. Third, the LRFFT threatens the resilience of the coral reef ecosystems by removing key predator species (Sadovy et al. 2003b; Sadovy 2006c).

Trade Prices and Value of LRFFT

Commercially, humphead wrasse have fetched top dollar with wholesale prices steadily rising over the years. Prices have risen from US$ 62/kg in the early 1990s to as much as US$ 130-180/kg for more recent market prices (Johannes and Riepen 1995; Sadovy et al. 2003a; Pinnegar et al. 2006). The consumption of rare species as luxury food items, particularly in Hong Kong and mainland China, is a way of displaying wealth and/or social status (Courchamp et al. 2006; Fabinyi 2011). The more rare the item, the more expensive and prestigious it is to consume. A single, large 40 kg humphead wrasse can sell for over US$ 5,000 (Erdman and Pet-Soede 1997), with the lips alone fetching between US$ 225-460 (Johannes and Riepen 1995; Erdman and Pet-Soede 1997; Courchamp et al. 2006; Yan 2011). Affluent Asian executives are known to consume a plate of lips when closing large business deals (Courchamp et al. 2006). The cheeks and skin of humphead wrasse also are said to fetch extremely high prices in specialty restaurants (Johannes and Riepen 1995).

Humphead wrasse are more lucrative alive than dead. Fishers are paid 2 to 25 times more for a live fish than dead fish, and fishers supplying live fish for the trade earn 3 to 10 times the average salary of non-participating fishers (Erdmann and Pet-Soede 1997; Pet-Soede and Erdmann 1998; Sadovy et al. 2003a). Prices fluctuate more widely compared to other high-value species and tend to peak during festive periods (Sadovy et al. 2003a). Total retail value of high-value species in the LRFFT, such as humphead wrasse, imported into Hong Kong is estimated between US$ 125 million (Sadovy et al. 2003b) and US$ 1 billion (Barber and Pratt 1997).

Volume of LRFFT

International trade volumes are difficult to determine because of poor or lack of recording in many places (such as out of the Philippines and into mainland China [Sadovy unpublished]). Conservative past estimates of the annual volume of Asian trade in live food fish, including humphead wrasse, was between 20,000-32,000 tons (t [Barber and Pratt 1997; Chan 2001]). For *C. undulatus*, the estimated annual import volume into Hong Kong was between 9 and 189 t between 1997 and 2008, peaking in 1997 and declining to < 10 t in both 2007 and 2008 (Sadovy de Mitcheson et al. 2010). Gillett (2010) reports trade of humphead wrasse for the period of 2000-2006 ranged from 58 to 138 t. These numbers are believed to be substantial underestimates because much of the trade is unmonitored and illegal as indicated by traders, biologists, government officials, and through regular confiscation of imported fishes in Hong Kong (Sadovy de Mitcheson et al. 2010). Although data are sparse, some discrepancies in trade volume are noted in trade databases. For example, Indonesia set a national export quota of 8,000 fish in 2005, and although data identified that 5,320 live *C. undulatus* were exported to Hong Kong, further analysis suggests that the export data from Indonesia were inaccurate and much higher than what was reported (Sadovy 2006a).

Overall, several shortcomings with estimates of trade and landing volumes exist, resulting in a likely underestimate of overall trade volumes using official figures. These shortcomings include: 1) a significant under- and misreporting of the trade in live reef fish, as well as illegal trade, especially in the key exporting countries of Indonesia, Malaysia, and Philippines; 2) mortality rates of live reef fish between capture and consumer can be considerable, especially transport via boat, and may go unrecorded entirely; 3) there were no customs inspections at import into Hong Kong to verify species noted on import forms (e.g., the species has been mislabeled as grouper in Indonesia); 4) some source countries were not recorded in the Agriculture, Fisheries and Conservation Department of the Hong Kong government's voluntary data collection scheme; and 5) there were no re-export data between Hong Kong and mainland China (Johannes and Riepen 1995; Sadovy 2003a; Sadovy 2010; Gillett 2010).

Although the LRFFT does not operate in most countries where the humphead wrasse occurs, a considerable portion of the species' habitat does occur in the three most important live fish supplying countries of Indonesia, Malaysia, and the Philippines. According to Spalding and Grenfell (1997), total estimated regional coral reef areas rounded to the nearest thousand in South East Asia totals 68,000 km^2. Per Gillett (2010), the LRFFT may therefore be having an impact on the overall biomass of the humphead wrasse (Gillett 2010).

5.2.2.2. Harvest of Juveniles for LRFFT, Marine Aquarium Trade, and Mariculture. The preferred size of the species in all forms of trade is juveniles (< 50 cm TL). Per Hong Kong interviews, although medium-large humphead wrasse (5-40 kg/fish) taste better, many consumers prefer "plate-size" humphead wrasse (0.6-5 kg/fish) (Sadovy 2006b). The reasons for shift in size preference since the mid-1990s are due to cost of the fish and a reduced risk from ciguatoxic poisoning in smaller fish (Sadovy 2006a). When 2,310 live humphead wrasses were measured in Hong Kong markets from 1995 to 2009, body sizes were predominantly (~76%) < 50 cm TL (Sadovy de Mitcheson et al. 2010). In Yap, 75% of market humphead wrasses (sample size not specified) were < 40 cm TL (Houk et al. 2011). These data may indicate an international live trade largely focused on juvenile to sub-adult fish that are below the reported mean reproductive size (mean reproductive size is variable (Table 1) [Figure 15]).

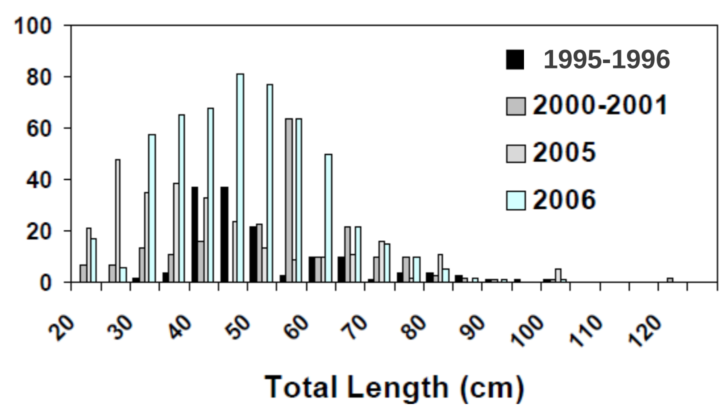

Figure 15.--Size-frequency distributions of humphead wrasse (n=not specified) in the Hong Kong retail sector during four different survey periods, 1995-1996, 2000-2001, 2005, and 2006. The most recent data (2005/2006) show that most fish are retailed < 50 cm in TL and many are at or below the approximate size of sexual maturation. (Source: Sadovy 2006a)

Very little information is available on the level of harvest of juvenile humphead wrasse for the marine aquarium trade. The quantity of humphead wrasse in the aquarium trade is estimated to be 10% of the total weight of all humphead wrasse captured (Gillett 2010 citing Indonesian Directorate General of Forest Protection and Nature Conservation 2006) (Figure 13). In Indonesia, recruitment to the aquarium fishery occurs at a very small size (i.e., 62 mm FL; Choat et al. 2006), but no information is available on the number of fish that are captured in the fishery. Wada et al. (1993) suggests that the species is frequently exhibited in commercial Japanese aquariums, but there are no quantitative estimates of the number and origin of fish collected for this purpose. While humphead wrasse have been observed on display in commercial aquariums, the trade of humphead wrasse for personal aquaria is not likely due to the large size obtained.

While true mariculture of the species (i.e., broodstock spawn and larval fish raised in captivity at commercial levels) is not highly successful (CITES 2010b; Sadovy et al. 2011), the grow-out of small, wild-caught, humphead wrasse is commonly practiced in Indonesia, Malaysia, and the Philippines (CITES 2010b). Juvenile – sub-adults, typically 20-40 cm TL, are regularly collected from the wild and raised in floating net cages until saleable size (i.e., fish of ≤ 300 g are grown to 400 g [CITES 2010b citing Bentley 1999]). This appears to be one way to circumvent legal size limits on this species. The impact of juvenile grow-out on adult stocks depends on the sizes and numbers of fish taken and their likelihood of reaching sexual maturity. Given the quantity of juvenile fish taken from the wild for mariculture grow-out, the impact to the overall population is likely to be considerable if most would have survived to reach sexual maturity (Sadovy et al. 2003a). Regarding mariculture for population restoration, restocking has not yet proved effective in restoring populations of exploited marine fishes in general and is not applicable to humphead wrasse (CITES 2010b).

5.2.2.3. Overexploitation of Spawning Sites. Spawning aggregation sites may be vulnerable to exploitation from commercial fisheries since experienced cyanide divers are skilled in locating them. Although removing fish such as the humphead wrasse from one aggregation site can eliminate top predators from several square miles of reef (Pet and Pet-Soede 1999), the use of cyanide collection techniques to collect an active fish up in the water column is not likely. Colin (2010), however, disagrees that spawning sites are overly vulnerable, likely since the size of spawning fish are outside the smaller-sized humphead wrasse that restaurants prefer. He notes that Palau has ≥ 50 resident aggregations of C. undulatus along the outer barrier reef and these aggregations are much more numerous than for other species such as groupers.

5.2.2.4. Illegal, Unregulated or Unreported Fishing. Reports of illegal, unregulated, or unreported (IUU) fishing, particularly commercial fishing, are prevalent in the literature but have not been quantified; therefore, local or global impacts on humphead wrasse populations are unknown. Yan (2011) and Traffic (2007) report that in December 2006, illegally-caught fish – including 359 juvenile humphead wrasse – were confiscated from the M/V Hoi Wan, a Chinese fishing vessel registered in Hong Kong that was apprehended in Palawan, Philippines (Sadovy (2010) reports the number to be 1,200 humphead wrasse that were confiscated; it is unknown why this report is so vastly different from the other two reports). The vessel was seized after being found illegally fishing in the waters off of the protected Tubbataha Reef National Marine Park in the Sulu Sea. The find remains one of the most significant wildlife apprehensions in Philippine history. In addition, Sadovy de Mitcheson et al. (2010) assessed 178 humphead wrasse specimens that were confiscated from entering Hong Kong from 2006-2009. Given that a high proportion of C. undulatus entering Hong Kong come from Indonesia and that approximately 77.5% of the confiscated fish that came from Indonesia were < 50 cm TL with 68.5% < 40 cm TL, it is clear that a significant proportion of captures and exports from Indonesia are of immature juveniles. This finding is significant because Indonesian national regulations prohibit export of the species when < 1 kg (c. < 42 cm TL).

Illegal, destructive fishing practices such as those used in the IUU trade are the easiest and most profitable way to harvest shy species such as humphead wrasse. Blast fishing (used to catch feed fish for grow-out pens) and cyanide fishing equipment are inexpensive, easy to dispose of to avoid prosecution, easy to replace, and can increase profits up to ten-times if the fish is captured alive (Pet-Soede et al. 1999; Spait 2001; Bailey and Sumaila 2008). These highly destructive fishing practices continue due to the lack of enforcement. However, the lack of enforcement rather than a lack of regulation may be the key driver in promoting IUU activities (Spait 2001; Poh and Fanning 2012). Moreover, until fish can be identified for their geographic origin and cyanide-free fishing practices, illegally sourced fish can be legally sold (Poh and Fanning 2012). Overall, the four key factors contributing to the persistence of IUU trade are: 1) lack of capacity for enforcement; 2) lack of disincentives; 3) lack of accountability and traceability; and 4) lack of control over domestic trade (Poh and Fanning 2012) in both importing and exporting countries.

5.3. (C) Disease or Predation

Very little is known about diseases of the humphead wrasse other than fish leech infestation (*Hirundinea* sp.), parasitic infestations (protozoa, worms, etc.), and bacterial infections that have been documented. Parasitic infestations have been reported as occurring in the fins, gill operculum, body surface, eyes, and mouth cavity (Koesharyani et al. 2005; Zafran et al. 2005). Zafran et al. (2005) report that cryptocaryoniosis, or white spot disease because it causes numerous white spots on the body surface, is the most dangerous parasitic disease in many marine fishes in aquaria or mariculture facilities. This disease, which can spread rapidly to other healthy fish and lead to a high mortality, has been documented at the Gondol Research Station in Indonesia. The Gondol Research Station has also reported the presence of the parasitic disease oodiniasis (*Amyloodinium ocellatum*, a dinoflagellate protozoan) infecting captive humphead wrasse at their facility (Zafran et al. 2005), as well as capsalid monogenean, or so-called skin flukes, which are the most common external parasites in mariculture finfish (Koesharyani et al. 2005). Vibriosis, the most common bacterial disease in marine finfish, has also been documented in broodstock and young humphead wrasse at the Gondol Research Station. The infected fish were those that were captured with cage traps and transported to the station; mortality occurred within a week after the transportation (Zafran et al. 2005).

Wada et al. (1993) documented the first known report of a simultaneous infection with an acid-fast bacterium (*Mycobacterium* sp.) and an imperfect fungus in a humphead wrasse that was captured in Indonesia and reared in a commercial fish dealer’s concrete aquarium in Japan. They speculate that the male fish became infected while in captivity. No other information has been found to indicate that disease, particularly in the wild, is a factor influencing mortality of humphead wrasse.

There are no known major predators of adult humphead wrasse. Even in vulnerable locations such as at spawning aggregations. Colin (2010) reports that no instances of predation on spawning adults were observed despite the presence of grey reef (*Carcharhinus amblyrhynchos*) and white tip (*Trianodon obesus*) reef sharks. Additionally, few other piscivorous reef fishes are capable of taking even a moderate-sized *C. undulatus* (Colin 2010). The predators of juvenile humphead wrasse are unknown but likely to be sharks and other large-bodied piscivorous species such as grouper (Serranidae), Jacks (Carangidae), and snapper (Lutjanidae) that are commonly found on Indo-Pacific coral reefs.

5.4. (D) Inadequacy of Existing Regulatory Mechanisms

Existing regulatory mechanisms may include federal, state, and international regulations. Below is a description of current domestic and international management measures that affect the humphead wrasse.

5.4.1. Domestic Fisheries Management Authorities and Regulations

Federal fishing regulations that directly or indirectly control the harvest of species for the Western Central Pacific Ocean under U.S. jurisdiction are developed and enacted by the Western Pacific Regional Fishery Management Council and NMFS. The humphead wrasse is one such species that has specific fishing regulations in place. For the 2013 calendar year for the U.S. Territories, the humphead wrasse was subject to a federal annual catch limit set at 5% of the total estimated stock biomass of each island area (discussed in Section 3.4.). These catch limits are as follows: American Samoa: 1,743 lb; Guam: 1,960 lb; and CNMI: 2,009 lb (NMFS 2010; 78 FR 15885, March 13, 2013). These limits remain the same in 2014 (79 FR 4276, January 27, 2014).

Although an annual catch limit for the humphead wrasse is federally authorized, territories may enact local regulations to protect the species. This is the case with American Samoa where the Department of Marine and Wildlife Resources strictly prohibits any interaction with the species (i.e., possess, sell, kill). While the CNMI (Division of Fish and Wildlife) and Guam (Department of Agriculture) have not enacted a complete moratorium on fishing for the species similar to American Samoa, they have implemented gear and use restrictions that significantly limit capture (Table 10). The allowable gear lists for each island area are codified as follows: American Samoa (50 CFR 665.127); Marianas (Guam and CNMI) (50 CFR 665.427); and PRIAs (50 CFR 665.627). Generally, these federal regulations prohibit fishing with non-selective and destructive gear types (e.g., poisons, explosives, unattended gillnets, etc.).

No-take MPAs for the U.S. Pacific Islands region may also protect the humphead wrasse. In American Samoa, there are six federally managed MPAs, including the Fagatele Bay Marine Sanctuary, the Rose Atoll National Monument, as well as four MPAs under the jurisdiction of the National Park Service. There are also 11 village MPAs that are co-managed by communities and the local government. Throughout American Samoa the take and possession of the humphead wrasse, among other species, is banned (American Samoa Annotated Code Section 24.0962; American Samoa Executive Order 002-2012). In Guam, through Public Law 24-21, marine preserves have been established that prohibit the take of the species. In the CNMI, there are four no-take marine protected areas: Sasanhaya Fish Reserve on Rota, the Mãnagaha Marine Conservation Area, Bird Island Marine Protected Area, and the Forbidden Island Marine

Protected Area on Saipan. The Tinian Marine Protected Area allows for the harvest of seasonal runs of juvenile goatfish (Mullidae), rabbitfish (Siganidae) and jacks (Carangidae), as well as seasonal runs of Atulai (bigeye scad [*Selar crumenophthalmus*]). Several other regulatory

Table 10.--Domestic humphead wrasse regulations and/or conservation actions by U.S. Territory. (Source: NMFS)

U.S. Territory	Humphead Wrasse Regulations / Conservation Actions
American Samoa	• Listed as a rare marine species, it is prohibited to possess, deliver, carry, transport, ship, import, export, sell, offer for sale, take or kill the humphead wrasse. If the species is caught or captured, it shall be immediately released, whether dead or alive. It is not a defense that the species was caught or captured inadvertently, as bycatch, or from another fishery (American Samoa Executive Order 002-2012). • The National Marine Sanctuary of American Samoa is comprised of six protected areas, covering 13,581 square miles of nearshore coral reef and offshore open ocean waters across the Samoan Archipelago (77 FR 43942). Destructive fishing methods such as poisons, electrical charges, and explosives are prohibited within the Sanctuary. • Any type of fixed net or drift gill net is prohibited within the Sanctuary. • SCUBA spearfishing is prohibited within the Sanctuary.
CNMI	• Listed as a Species of Special Concern by CNMI Division of Fish and Wildlife.* • Four no-take MPAs are designated in the CNMI: Sasanhaya Fish Reserve on Rota; Mãnagaha Marine Conservation Area surrounding Mãnagaha Island on Saipan, as well as the Bird Island MPA, and Forbidden Island MPA. • Explosives, poisons, electronic shocking devices, SCUBA, or hookah while fishing is prohibited. • No person shall use drag nets/beach seines (Chenchulun and lagua), trap net (Chenchulun managam), surround net (Chenchulun Umesugon) or gill nets (Tekken) for taking of fish or other sea life. • No person shall possess, sell, or purchase any fish, game, marine, or other aquatic life taken by means prohibited in this section. • Use of any of these nets or devices will result in the net or devices being confiscated and the owners will be subject to penalties (fines and/or imprisonment). • Fishing gear that is substantially destructive to benthic substrate is prohibited. • The sale or export of marine aquarium fish is prohibited.
Guam	• Gill and surround gear net restrictions include: Surround nets must be removed within six hours of setting. All aquatic animals prohibited from take or which do not meet take requirements must be released immediately once determined to be in the net. All animals killed during the take must be recovered and removed from the waters of Guam (no marine finfish are "prohibited"). Gill nets for commercial harvest of aquatic animals is prohibited. • Place-based fishing restrictions for the following marine preserves: Tumon Bay, Agana Boat Basin, Piti Bomb Holes, Sasa Bay, Achang Reef Flat, and Pati Point. • Bill 11-32 (COR) – bans SCUBA spearfishing (introduced in January 2013 but not yet passed)
PRIAs	• No fishing of any fish including the humphead wrasse within 12 nm of Rose Atoll, Howland, Baker, and Jarvis Islands, Kingman Reef, Johnston Atoll, Wake Atoll, and Palmyra Atoll. ** • Beyond 12 nm, only allowable fishing gear/methods are permitted.

* The CNMI's Division of Fish and Wildlife's designation of the humphead wrasse as a "Species of Special Concern" has no implications to harvest or management.
**Essentially a complete ban on the collection of the species since there is no coral reef habitat outside of 12 nm.

mechanisms exist in the CNMI that reduce both fishing power and fishing mortality such as the ban on the use of SCUBA and hookah to spear fish, and restrictions on the use of gill, surround, and drag nets (CNMI Administrative Code Subchapter 85-30.1). For the PRIAs, federal law prohibits fishing for any management unit species, including humphead wrasse, within 12 nm of the following areas: Rose Atoll, Howland, Baker, and Jarvis Islands, Kingman Reef, Johnston Atoll, Wake Atoll, and Palmyra Atoll (78 FR 32996; June 3, 2013).

5.4.2. International Authorities and Regulations

Two international authorities have been useful in focusing considerable attention on the humphead wrasse: the IUCN Red List of Threatened Species, which conducts assessments of species' extinction risk on a worldwide basis using the best available data, and CITES, which regulates international trade of species. In 1996, the humphead wrasse was listed as "vulnerable" on the IUCN Red List of Threatened Species due to concerns over rapidly declining numbers in many areas. In 2004, the species was reclassified to "endangered." (Ratings of species range from least concern, vulnerable, endangered, critically endangered, extinct in the wild, and extinct.) Listing a species on the IUCN Red List does not provide any regulatory protection for the species, but serves as an evaluation of the species' population status.

In 2002, the humphead wrasse was proposed for listing in Appendix II at the 12th meeting to the CITES Conference of the Parties (CoP). However, the Parties failed to reach a consensus vote. At the 13th CoP in 2004, the listing was again proposed for Appendix II and passed by consensus vote making it the first commercial reef food fish species to be listed in an Appendix (Sadovy 2006c; Sadovy unpublished). Appendix I includes species threatened with extinction under CITES criteria; international trade of these species is permitted only in exceptional circumstances. Appendix II includes species that are vulnerable to overexploitation, but not at risk of extinction under CITES criteria; international trade must be regulated to avoid exploitation rates incompatible with species survival. Appendix III contains species that are protected in at least one country, which has asked other CITES Parties for assistance in controlling the trade; the purpose is to address questions of legal origin, not sustainability. Through a permitting system, both exporting and importing countries play a role in ensuring that trade is conducted sustainably. Both an export permit as well as a non-detriment finding must accompany an Appendix II-listed species. These documents demonstrate that the export was legally acquired and that the export will not be detrimental to the survival of the species. For fisheries resources, in general, this requirement has been interpreted to mean that in the exporting country there must be a functional management plan and associated monitoring (Gillett 2010). The importing country has a responsibility to monitor imports of this species closely. If sustainability cannot be demonstrated, then the Convention enables sanctions on exports, leading to a strong incentive to comply (Sadovy 2006c).

The listing in Appendix II indicates that CITES Parties believed the humphead wrasse, while not threatened with extinction under CITES criteria, was at risk if international trade was not regulated (Sadovy unpublished). With international attention now focused on the humphead wrasse, countries can request technical assistance to comply with CITES requirements, including requesting funding to develop new stock assessments, and develop monitoring and management approaches for the species (Gillett 2010; Sadovy 2010). Funding has also been allocated to better understand the IUU trade of the species. This will aid in improving enforcement and compliance and moving towards more sustainable and legal international trade (Sadovy 2010).

5.4.3. International Workshops and Outcomes

After the CITES Appendix II listing became effective in January 2005, a number of workshops to conserve the humphead wrasse were held over the years. For example, the 15th CITES CoP in 2010 recognized that IUU activities in the LRFFT continued to undermine efforts to protect the species, and that additional management measures were needed to combat IUU fishing (CITES 2010a; CITES 2010c). Recommendations included: prohibiting the catch of immature (< 50 cm TL) fish; establishing protected areas for adult fish; developing a procedure for cyanide testing; establishing national traders associations; establishing protocols for vessels operating in Indonesia; coordinating interagency inspections at airports; and tagging and validating shipments for CITES enforcement (CITES 2010a). Recommendations from other subsequent workshops included: building regional cooperation; promoting collaboration between agencies; identifying remaining data and information gaps; developing a stock assessment model to determine sustainable export quota for the species; developing guidance on mariculture; and standardizing survey methods in assessing wild humphead wrasse populations (CITES 2006; Gillett 2010; Sadovy et al. 2011). While these are only recommendations at this point, they may in time become regulations.

5.4.4. International Fisheries Management Regulations

Globally, the "endangered" listing on the IUCN Red List, the CITES Appendix II listing, and the suite of international workshops have all brought a great amount of international attention and action to the conservation of the humphead wrasse. Nationally and locally, many countries and provinces have taken the next step by advancing recommendations into fisheries management regulations specific to the humphead wrasse (Table 11). Although the species occurs in 48 countries and less than half of these countries have implemented regulations that protect this species, perhaps regulations are non-existent for these other countries because either the abundance of the species is unknown or not documented in the literature (e.g., Cambodia, Egypt, Kenya, Saudi Arabia, Somalia, Sudan, etc.), and/or these other countries have not participated in the legal international trade of the species (e.g., Djibouti, Eritrea, Israel, Madagascar, Mayotte, Myanmar, etc.). In fact, according to CITES, only 12 countries participate in the legal trade of the species (Table 12). Regardless of the regulation – catch limits, gear restrictions, MPAs, etc. – national rules that have been adopted as local rules are perceived by residents as achieving greater compliance than either purely local or purely national rules (World Bank 2000).

Table 11.--International regulations and/or conservation actions of humphead wrasse by implementing country. (Source: Russell 2004, unless cited otherwise)

Country	Date	Humphead Wrasse Regulations / Conservation Actions
Australia		Capture of humphead wrasse for both live and frozen markets is prohibited (Sadovy et al. 2003b).
	2003	Queensland: Coral Reef Fin Fish Management Plan prohibited all take and possession of humphead wrasse, other than for limited educational purposes and public display.
	1998	Western: Complete protection because stocks determined to be insufficient and susceptible to overfishing.
British Government		Chagos Marine Reserve: No-take MPA out to 200 nmi; includes 55 islands and over 250,000 km^2 of reef & habitat. Largest reserve in world (Western Pacific Regional Fishery Management Council 2013).
China		Permits are required for the sale of this species in Guangzhou province, southern mainland China, for conservation purposes.
Fiji	2004	Ban on SCUBA-assisted spearfishing; ban on night free-dive spearfishing (Western Pacific Regional Fishery Management Council 2013).
		Ban on the commercial take, capture for sale, offer for sale, or possession of live or dead specimens of humphead wrasse (Gillett and Moy 2006; Sadovy de Mitcheson et al. 2010). The ban is slated to expire Dec 31, 2014 (Gillett and Moy 2006).
Federated States of Micronesia		Ban on export for LRFFT (Western Pacific Regional Fishery Management Council 2013).
Indonesia	1985; 1995	Regulation 375/Kpts/IK.250/5/95 prohibits the capture of humphead wrasse except for research and traditional fisheries (Sadovy et al. 2011). Allowable fishing methods are hook and line, fish trap, and gill net.
		Fisheries Law No. 9 (1985) prohibits the use of destructive fishing techniques such as explosives and poison. Penalties are up to 10 years of jail and/or US$ 1.7 million dollar fine (Pet and Pet-Soede 1999).
		Commercial export of < 1 kg and > 3 kg is prohibited. However, under specific conditions, local fishers are able to sell humphead wrasse to aquarium collecting companies that have obtained a business permit (Sadovy et al. 2003b).
	2013	Export quota of 1,800 fish per year total amongst all of the provinces (down from 8,000 in 2005) (IUCN 2013).
Kiribati	2007	Phoenix Islands Protected Area: 157,626 m^2 of MPA where fishing and other extractive activities are banned or highly regulated (Western Pacific Regional Fishery Management Council 2013).

Table 11 *continued*

Malaysia	2010	Malaysia reduced their export quota to zero and they continue to maintain a zero export quota (Sadovy 2010; IUCN 2013). Leading up to this ban, the Department of Fisheries Sabah and other management agencies decided to buy back some of the remaining stocks of humphead wrasse that were being held in cages by exporters in remote islands in Sabah. A total of 885 fish were purchased and 874 were released at 4 sites around Sabah that were kept confidential to reduce the potential for poaching of newly released fish (Kassem and Wong 2013).
Maldives	1995	Ban on all exports of humphead wrasse, largely due to concern for recreational diving, a sector that values this species.
New Caledonia		All exports of humphead wrasse are banned (Sadovy et al. 2003a).
Niue		The interference, take, kill, or bringing to shore of the humphead wrasse is prohibited without written approval. All exports of humphead wrasse are banned (Sadovy et al. 2003a).
Palau	2006 2014	Illegal to fish, buy or sell humphead wrasse. Export has been banned since 1998 (Gillett 2010). All commercial fishing for any marine species is planned to be banned within the 200 nautical mile exclusive economic zone (Lederer 2014).
Papua New Guinea		There is a 65 cm TL minimum size limit for exporting humphead wrasse but this does not prevent fishers from catching and holding smaller humphead wrasse in cages (culturing) until they attain 65 cm TL. All live fish operators are required to obtain licenses. Species can no longer be exported (Sadovy de Mitcheson et al. 2010).
Philippines	 1990s 1994 1998	Bans exports of CITES marine species. The Philippines Cyanide Fishing Reform Program implemented policy reforms in source and consumer countries to create anti-cyanide fishing incentives and enforcement mechanisms as well as development of partnerships with fishing communities, focusing on transfer of non-destructive technology and improvement of local livelihoods (Barber and Pratt 1997). The Wildlife Resources Conservation and Protection Act (Republic Act of 9147) allows collection of humphead wrasse solely for scientific, breeding, or propagation purposes. The commercial trade of the species, whether for seafood or the aquarium trade, is punishable by law (Yan 2011). Possession of humphead wrasse is prohibited under Section 97 of Republic Act 8550 of the Fisheries Code, with stiff fines for illegal possession.

Table 11 *continued*

Samoa		No person shall SCUBA fish without a license, and many different types of traditional rules (e.g., MPAs, minimum size limits, and restricting use of underwater lights when spearfishing) exist in 324 villages (Western Pacific Regional Fishery Management Council 2013).
Seychelles	2005	Bans all live fish exports (Gillett 2010).
Solomon Islands		Ban on night free-dive spearfishing (Western Pacific Regional Fishery Management Council 2013).

5.4.5. Adequacy of Existing Regulatory Mechanisms

Since sustainable management regimes can have periods of stasis or even declining populations, it is difficult to measure the global adequacy of existing regulatory mechanisms as they relate to the humphead wrasse's population worldwide. Reference may be given to the international authorities of CITES and IUCN as a proxy for population status. However, neither classification is an inherent indication that the species may now warrant threatened or endangered status under the ESA.

Overutilization

Given that humphead wrasse are naturally rare/uncommon, cannot sustain much fishing pressure, and is mostly caught in fisheries that are notoriously difficult to monitor, a number of countries and provinces have enacted regulations to protect the species (see Tables 10 and 11). These regulations include banning the take of the species, banning export, regulating minimum size limits, implementing gear restrictions, or establishing no-take MPAs. As a result, legal trade of the species has decreased substantially. According to the CITES trade database (CITES 2014), 12 countries report trade in the species, ranging from live humphead wrasse to bodies, derivatives, and meat; of these 12 countries, only 10 countries report exporting live humphead wrasse. From 2005-2011, 81,848 live humphead wrasse were legally traded by 10 countries, whereas in 2012, only 1,691 live humphead wrasse were legally traded by 5 countries. Zero bodies, meat, or derivatives of the species were traded in 2012 (CITES 2014).

Legal trade has significantly decreased due to reduced or zero export quotas, especially from the main exporting countries of Indonesia, Malaysia, and the Philippines. For example, as of 2013, Indonesia has a significantly reduced export quota of 1,800 humphead wrasse, down from 8,000 originally instituted in 2005 (IUCN 2013), and legally traded only 1,653 in 2012 (CITES 2014). In 2010, Malaysia reached and has maintained a zero export quota of the species (Sadovy 2010; IUCN 2013; CITES 2014). This is significant since Malaysia legally exported ~53,000 live humphead wrasse from 2007-2009 (CITES 2014) (Table 12).

Table 12.--Summary for the world gross export trade in humphead wrasse: 2005 to 2012 (2005 is the first year the species was listed under CITES; 2012 is the most recent year for which the World Conservation Monitoring Centre (WCMC) has complete/readily available CITES trade data). Data taken from a gross report run from the United Nations Environment Programme-WCMC CITES Trade Database on July 18, 2014. Database can be found at http://trade.cites.org/#). Exporting country codes: FM = Federated States of Micronesia, ID = Indonesia, MY = Malaysia, AU = Australia, HK = Hong Kong, JP = Japan, NL = Netherlands, PG = Papua New Guinea, PH = Philippines, SG = Singapore, TO = Tonga, and SB = Solomon Islands. (Source: CITES 2014)

CITES Gross Exports Report

App.	Taxon	Term	Unit	Country	2005	2006	2007	2008	2009	2010	2011	2012
II	Cheilinus undulatus	bodies		FM							3	
II	Cheilinus undulatus	derivatives		ID							100	
II	Cheilinus undulatus	derivatives		MY					66			
II	Cheilinus undulatus	live		AU	17	41	1	15	6	4	5	32
II	Cheilinus undulatus	live		HK		2						
II	Cheilinus undulatus	live		ID	5230	864	6234	3809	4220	3810	2925	1653
II	Cheilinus undulatus	live		JP					1	5		2
II	Cheilinus undulatus	live		MY		1	17500	21600	13799			
II	Cheilinus undulatus	live		NL							3	2
II	Cheilinus undulatus	live		PG			784	210				
II	Cheilinus undulatus	live		PH		1		2				
II	Cheilinus undulatus	live		SG	2							2
II	Cheilinus undulatus	live		TO						757		
II	Cheilinus undulatus	meat	kg	SB						679.1		
II	Cheilinus undulatus	meat		MY					26290			

To further combat overutilization of the humphead wrasse, countries have increased adherence to CITES regulations. For example, Hong Kong has introduced several CITES-related permits to better control trade. Hong Kong now checks all imports and re-exports, and coordinates verification of CITES permits with Malaysia and Indonesia (Sadovy 2010). As previously stated, major exporting countries have either reduced quotas following recent CITES non-detriment findings (e.g., Indonesia) or implemented a zero export quota (e.g., Malaysia) (Sadovy unpublished; IUCN 2013). Other countries that formerly exported humphead wrasse for the LRFFT have also banned the export of the species (e.g., Australia, Federated States of Micronesia, New Caledonia, Niue, and Palau) (Gillett 2010). National regulations have also been tightened (e.g., Fiji), thereby helping to close enforcement loopholes (Sadovy 2010).

Lastly, as a testament to recent regulations indicating a possible improvement in the status of the species, at least in some areas, recent field surveys were conducted in Indonesia at sites that had been designated as baseline study sites. Of the 7 baseline study sites, 4 have been recently resurveyed with increased densities noted at each site. Most fish are in their juvenile phase but the increase in numbers is encouraging and has occurred in areas where fishing pressure has evidently declined since the original surveys were conducted 4-5 years ago (IUCN 2013).

From an exposure perspective, CITES Appendix II-listing of the humphead wrasse is proving to be beneficial for conservation, as it has brought international “muscle” to enforcement (and thus helping to reduce IUU activities), funding for assessments, and structure to trade of the humphead wrasse. Continuing vigilance to more fully implement the CITES listing will help to ensure the sustainable use of the humphead wrasse for the long term (Sadovy 2010). However, despite the benefits of the existing regulations, shortcomings in the reporting of trade and landings, enforcement issues, and IUU fishing remain challenges to the efforts to reduce or prevent overutilization or to assist reduced populations to recover. Efforts to reduce IUU activities are discussed further below.

Destructive Fishing Practices

As for the threat of destructive fishing practices, though many countries prohibit the use of cyanide to catch fish, and though sufficient laws give authorities a legal basis to curb its use, cyanide fishing continues – mainly because of a lack of on-the-ground enforcement (Yan 2011). Since profit margins in the LRFFT are large enough to allow for substantial bribes, local officials either are paid to look the other way or may even be partners in the business (Erdman and Pet-Soede 1997; Pet and Pet-Soede 1999). In Indonesia, it is only illegal to use cyanide for fish capture; possession of cyanide on fishing vessels is permitted for “tranquilizing” purposes (Erdman and Pet-Soede 1997). In addition, detection of cyanide in a species is confounded by the rapid conversion of cyanide into other chemicals, thus requiring detection to be interpreted cautiously (Thornhill 2012). Loopholes such as this make enforcement virtually impossible, and with so much corruption, eradication of this illegal and destructive fishing method is extremely difficult (Erdman and Pet-Soede 1997; Pet and Pet-Soede 1999). However, since cyanide fishing is driven mostly by the international commercial trade in live coral reef fishes (Bruckner 2001), and with the legal trade of humphead wrasse in the LRFFT extremely reduced (i.e., 1,691 live humphead wrasse traded in 2012 versus the ~82,000 traded from 2005-2011), the threat of destructive fishing practices may be waning.

Illegal, Unregulated or Unreported Fishing

Many challenges still exist in combating IUU trade of humphead wrasse. For example, misreporting is an issue when humphead wrasse are sometimes labeled as groupers or hidden under groupers when sent out by air, or exports illegally sent via sea as indicated by confiscations in Hong Kong (CITES 2010a; CITES 2010b; Sadovy et al. 2011). Other challenges include transshipments through Singapore, which are often not documented, and Hong Kong not adequately enforcing restrictions on imports by sea. Additionally, under-reporting is considered a significant issue, resulting in a likely underestimate of the overall trade (Sadovy 2003a; Gillett 2010). To combat these issues, Hong Kong, the largest importer of the species, has recently committed to controlling imports, re-exports, and possession within the territory, thus enabling a more secure system of trade (CITES 2010a). Collaborations and/or funding involving the IUCN, the CITES Secretariat, and a number of other organizations have assisted in the above work (CITES 2010a). For example, a project sponsored by the U.S.

government in collaboration with the Trade Records Analysis of Flora and Fauna in Commerce (TRAFFIC) East Asia and World Wildlife Fund in the Philippines is being carried out to better understand the IUU trade of the species in order to improve enforcement ability and help to better determine how to improve compliance with the CITES listing and move towards a more sustainable international trade (Sadovy 2010). However, despite the efforts to reduce IUU trade in the species, recent examples can be found. On November 1, 2013, two humphead wrasse – one adult and one juvenile – were found in the freezer of a Suva fish factory that primarily exports tuna to Japan even when the take, possession, sale, etc. of the species is prohibited in Fiji (Gibson 2013). The take, possession, sale, etc. of the species is prohibited in Fiji.

Habitat Protection

As previously mentioned, the creation of MPAs is another measure to conserve the humphead wrasse from human-induced threats. In countries where some degree of protection for the species is afforded and enforcement is in place, local stocks in some regions appear to be stable (e.g., Australia, Maldives, and Wake Atoll). As previously noted, sites in Indonesia that were historically fished but are now protected have shown an increase in the number of juvenile humphead wrasse compared to 4-5 years ago (IUCN 2013).

A large number of MPAs exist globally, many of which are within the geographic range of the humphead wrasse. Domestically, no-take MPAs strictly prohibit fishing for humphead wrasse within 12 nm of Rose Atoll (Rose Atoll Marine National Monument), Howland, Baker, and Jarvis Islands, Kingman Reef, Johnston Atoll, Wake Atoll, and Palmyra Atoll (collectively, the Pacific Remote Islands Marine National Monument) (78 FR 32996, June 3, 2013). All territorial areas of American Samoa are a no-take area for the species, and a number of marine preserves for the species have been established in Guam. In addition, in February 2014, the President of Palau announced his plans to ban all commercial fishing within 200 nautical miles of the exclusive economic zone (Lederer 2014). According to the World Database on Protected Areas, MPAs range from 0.004 km^2 to 640,000 km^2 but the average MPA is small in scale, only 1 km^2 to 10 km^2 (Weng et al. in press citing IUCN and UNEP 2009). Weng et al. (in press) calculated that MPAs need to encompass nearly 25 km of reef in their largest dimension to serve as an effective management tool for *C. undulatus*. The authors assert that in order for MPAs to achieve 90% retention of the species, 77% to 94% of the existing 2,241 coral reef MPAs within the species' range are too small to protect the humphead wrasse effectively (Weng et al. in press) (Figure 16). While a majority of protected reefs in the Indo-Pacific fail to meet this standard, evidence suggests that MPAs of this scale can be successfully implemented over large regions (Weng et al. in press). The 344,000 km^2 Great Barrier Reef Marine Park, which constitutes one of the largest MPAs in the world, implemented a zoning plan in 2004 that establishes 20 km as the minimum length of the smallest dimension of any no-take reserve. As of 2009, nearly half of the 122 offshore reserves in the Great Barrier Reef Marine Park had been expanded to fit this definition (Fernandes et al. 2005).

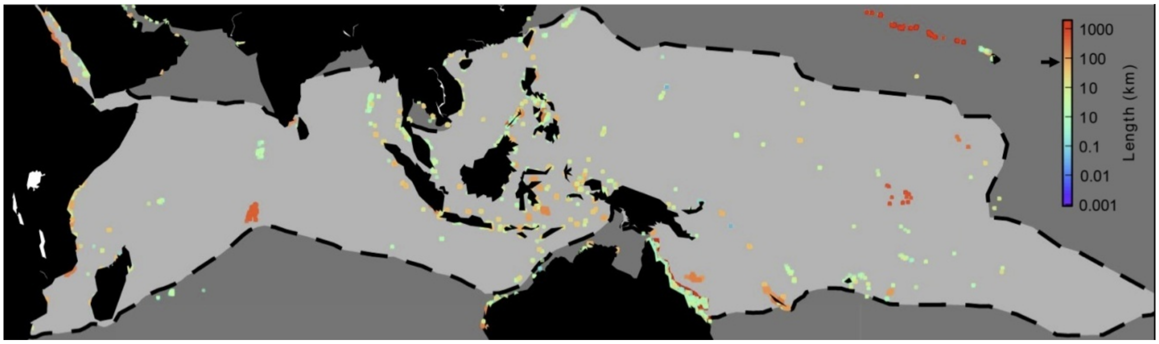

Figure 16.--Length dimension for MPAs in the Indo-Pacific region. Light gray region (bounded by dotted line) shows distribution of *C. undulatus* after Sadovy et al. 2003a. Colored dots show marine protected areas, with length scales given by the color bar. The largest MPAs are in red. (Source: Weng et al. in press)

In sum, this suite of regulatory measures is reasonably likely to benefit the humphead wrasse globally by appreciably reducing the threats to the species if they are enforced. Most specifically, one of the greatest threats, the LRFFT, has decreased substantially for humphead wrasse due to reduced or zero export quotas (CITES 2014). However, while beneficial, these measures will not ameliorate all of the threats (e.g., IUU fishing, etc.) unless regulatory measures are enforced. Moreover, it is speculated that at least a decade is necessary for a heavily exploited population to begin recovery from fishing pressure once protection is provided (Colin 2010). However, as indicated in recent surveys of humphead wrasse in Indonesia, an increase in population abundance has been noted at some sites after only 4-5 years of increased protection (IUCN 2013).

5.5. (E) Other Natural or Manmade Factors

5.5.1. Life History Characteristics

Similar to many large-bodied species, the humphead wrasse is slow growing, long-lived, and reproductive development is delayed (Choat et al. 2006; Tupper 2007; Sadovy de Mitcheson et al. 2008; Colin 2010). The vulnerability of this species is exacerbated by other factors as well. For example, adults often occupy consistent home ranges, have predictable sleeping sites, have discrete spawning locations, and may form mass aggregations during spawning (Sadovy et al. 2003a). Considering wide uncertainty in these life history characteristics, the estimated minimum population doubling time for the humphead wrasse has a wide range (4.5 to 14 years (Fishbase.org)).

In addition to analyzing life history characteristics of a species, the productivity of a species is a valuable parameter to assess. Population growth rate, often referred to as *r* (the intrinsic rate of increase) or productivity, is a complex function of fecundity, survival rates, age at maturity, and longevity. Productivity or *r* determines a species' ability to recover from low numbers, if extrinsic factors are not limiting, as well as the level of harvest that can be taken from a population sustainably (Hudson and Bräutigam 2007). For the humphead wrasse, an estimate of this intrinsic rate of increase derived from life history is 0.72 (Fishbase.org). There is no direct measure of this species' productivity. For context as well as comparison with other finfish, the *r* values range from very low productivity (r < 0.05), low productivity (r = 0.05-0.15, for example, sharks and orange roughy), medium productivity (r = 0.16-0.5, for example, cod, hake, and plaice), and high productivity (> 0.5, for example sardines and anchovies) (Caddy 2004; Gerber et al. 2005). As a comparison with other highly prized reef fish species in the LRFFT, the leopard coral grouper (*Plectropomus leopardus*), the mangrove red snapper (*Lutjanus argentimaculatus*), and the giant grouper (*Epinephelus lanceolatus*), have an estimated *r* = 1.54, 1.32, and 0.36, respectively (Fishbase.org). While the humphead wrasse may be more productive than a number of other finfish, it is not as productive as other reef fish such as the aforementioned that are highly exploited in the LRFFT.

Vulnerability levels are another predictor in a species' susceptibility to extinction. A fuzzy logic expert system integrated life history and ecological characteristics of marine fishes to estimate their intrinsic vulnerability to fishing (defined as the relative extinction risk resulting from fishing, disregarding other factors such as pollution or coastal developments). Vulnerability was reported on a scale from 1 to 100, with 100 being the most vulnerable (Cheung et al. 2005). The humphead wrasse was rated 74 out of a scale of 100, indicating high to very high vulnerability (Fishbase.org). Overall, a number of life history characteristics of the humphead wrasse may make it more susceptible to natural and human perturbations.

5.5.2. Competition

The humphead wrasse is an opportunistic diurnal carnivore. Their wide-ranging diet includes molluscs, small fishes ranging from gobies to boxfish, morays, sea urchins, crustaceans, brittle stars, starfish, and other invertebrates such as worms and sea snails (Randall et al. 1978; Myers 1989; Randall et al. 1997; Thaman 1998; Pogonoski et al. 2002; Sadovy et al. 2003a; and Choat et al. 2006). In the trophic food web scale (which identifies the position a fish occupies on the food chain), the humphead wrasse is rated as a 4.0 (on a scale up to 5.0) and consumes organisms that are trophically rated at least 2.8 (Fishbase.org). It is also estimated that the species consumes 2.9 times its body weight in food per year (Fishbase.org).

As generalists, humphead wrasses are less susceptible to competition for prey (from other predators or fisheries) than species with more specialized diets. Although there may be some prey species that have experienced population declines, no information exists one way or another to indicate that depressed populations of these prey species are negatively affecting species abundance.

5.5.3. Climate Change

Because the humphead wrasse uses inshore habitats and coral reefs out to a depth of up to 100 m (Randall 1978; Sadovy et al. 2003a; Russell 2004; Zgliczynski et al. 2013) and beyond (Gerry Davis, pers. comm.) throughout much of the tropical Indo-Pacific Ocean, large-scale impacts such as global climate change may pose a threat to this species, though the extent, if any, is unknown. Humphead wrasses do not feed directly on corals but do inhabit coral reefs and, in some areas, branching corals serve as important settlement sites and juvenile nursery areas. As such, this section describes possible climate change impacts to coral reefs and how they may affect the humphead wrasse.

Per the Intergovernmental Panel on Climate Change (IPCC), principle changes occurring over anywhere from decades to centuries are expected to include: 1) an estimated rise of ocean temperatures in the top 100 m of about 0.6 to 2.0 °C; 2) a global mean sea level rise in the range of 0.17 to 0.82 m; 3) an increase in ocean acidity with pH falling 0.06 to 0.32 pH units due to increasing atmospheric and oceanic CO2; and 4) severe weather, currents, and potentially alterations in food chain dynamics (IPCC 2013). These changes in the environment, described in more detail below, are expected to have impacts to individual performance, productivity, population connectivity, and restructuring of ecosystems (e.g., Edwards and Richardson 2004; Munday et al. 2008). Although research shows that the marine community is already responding to climate change, the level of response differs throughout communities (e.g., Edwards and Richardson 2004; Wilson 2006; Logan et al. 2013).

5.5.3.1. Ocean acidification. While the impacts of ocean acidification specifically to humphead wrasse are unknown, the threat is anticipated to be greatest to marine taxa that build skeletons, shells, tests of biogenic calcium carbonate such as coral (e.g., Fabry et al. 2008; Guinotte and Fabry 2008; Pandolfi et al. 2011), and have dense carbonate otoliths (ear bones; Simpson et al. 2011). In a meta-analysis, abundances of species reliant on live coral for food or shelter consistently declined (e.g., Wilson et al. 2006; Pratchett et al. 2008), while abundance of some species that feed on invertebrates, algae and/or detritus increased (e.g., Wilson et al. 2006). As previously discussed, branching corals are one of several important habitats to various stages of humphead wrasse life cycle. As discussed in NMFS' proposed rule to list 66 species of coral under the ESA (77 FR 73220; December 7, 2012), vulnerability of a coral species to a threat is a function of susceptibility and exposure, considered at the appropriate spatial and temporal scales. With regard to localized variability, recent papers identify various mechanisms that can offset or buffer changes in seawater pH around coral reefs from ocean acidification, such as photosynthetic uptake of CO_2 by sea grasses and macroalgae in adjacent areas (Palacios and Zimmerman 2007; Manzello et al. 2012; Anthony et al. 2013), and biogeochemical processes within coral reef communities (Andersson et al. 2013). Other papers identify mechanisms that can exacerbate changes in seawater pH around coral reefs from ocean acidification, such as diurnal variability, that can amplify CO_2 in seawater around coral reefs (Shaw et al. 2013). Ultimately, the future effects of ocean acidification on coral reefs will be highly variable across coral taxa, space, and time.

Other direct and indirect linkages of ocean acidification effects to the humphead wrasse remain tenuous. The adult humphead wrasse does not appear to be food limited or space limited in any portions of its range. The species also appears to be adaptable to a variety of biotic and abiotic conditions given its wide geographic range and observations of it residing (foraging, sleeping) in both shallow and deep water. Additionally, some researchers have pointed out that increased CO2 (lower pH) leading to ocean acidification could enhance seagrass productivity (Palacios and Zimmerman 2007; Guinotte and Fabry 2008; Poloczanska et al. 2009), which may benefit juvenile humphead wrasse that rely on seagrass beds as nursery areas.

5.5.3.2. Increased ocean temperatures. Increased ocean temperatures on large spatial and temporal scales could generally impact current flow, productivity, physiological performance and behavior of coral reef fishes and survival of corals. For example, larval production and survival rates could be negatively impacted (e.g., Lo-Yat et al. 2010). However, small temperature increases might accelerate larval development and competency to settle, though larger temperature increases may be detrimental (Munday et al. 2008). Though tropical reef fish are highly sensitive to small increases in water temperature, at least one species can acclimate over multiple generations (Donelson et al. 2011).

Brainard et al. (2011) discusses how coral adaptation and acclimatization to increased ocean temperatures is possible; that there is intra-genus variation in susceptibility of coral to bleaching, ocean acidification, and sedimentation; that at least some coral species have already expanded their range in response to climate change; and that not all coral species are seriously affected by ocean acidification. Such adaptation and acclimation could reduce the impact of warming temperatures and allow populations to persist across their current range (Donelson et al. 2011; Logan et al. 2013). The exceptional complexity, extent, and diversity of coral reef habitat defy simplistic modeling of reef responses to climate change threats. Likewise, many aspects of the biology of reef-building corals contribute to complex responses to ocean warming. This includes capacity for acclimatization and adaptation to ocean warming, range expansion in response to ocean warming (Yamano et al. 2011; Yara et al. 2011), and contrasting ecological interactions resulting from ocean warming (Hughes et al. 2012; Cahill et al. 2013). All of these contribute to highly variable, complex and uncertain responses of reef-building coral species and in turn, coral reefs to climate change threats like ocean warming.

Acropora spp., in particular, vary widely in their susceptibility to climate change impacts. Foden et al. (2013) developed a framework for identifying the species most vulnerable to extinction from a range of climate change-induced stresses. Their evaluations included 797 species of reef building corals, including 165 species of *Acropora*, and incorporated species' physiological, ecological, and evolutionary characteristics, in conjunction with their predicted climate change exposure. The results indicate that just 8 of the 165 *Acropora* species have high overall vulnerability to climate change while the remaining 157 have low overall vulnerability, indicating they are the least vulnerable to extinction due to climate change stresses within this group. In fact, acroporids were highlighted as one of three coral families that have a mean climate change vulnerability score significantly lower than the mean for all corals. Other information also indicates that *Acropora* corals are some of the most resilient corals, able to re-grow and recover in several examples of post-disturbance reef recovery (Adjeroud et al. 2009; Diaz-Pulido et al. 2009; Osborne et al. 2011).

5.5.3.3. Sea level rise. The IPCC (2013) predicts that the global mean sea level will continue to rise during the 21st century due to increased ocean warming and increased loss of mass from glaciers and ice sheets. Sea level rise of 0.26 to 0.97 m (IPCC 2013) could promote human depopulation of certain areas, particularly within low-lying tropical regions. This could perhaps relax fishing pressure, providing a benefit to humphead wrasse.

The impacts of sea level rise to coral reef ecosystems remains uncertain. Theoretically, a rise in sea level could potentially provide additional habitat for corals living near the sea surface. There are now studies documenting that during periods of higher water levels, coral cover increases on reef flats (Brown et al. 2011; Scopélitis et al. 2011). On the other hand, if coral growth is unable to keep pace with sea level rise, there may be negative consequences such as a buildup of sediments, etc.

5.5.3.4. Extreme weather. Extreme weather events including storms, cyclones, and heavy rainfall events such as monsoons are likely to become more intense and more frequent by the end of this century as global mean surface temperature increases (IPCC 2013). The influx of fresh water could increase turbidity in coastal waters and could cause rapid drops in salinity thereby affecting the stability of coastal waters, including nearshore reefs where humphead wrasse can be found. An influx of nutrients from sedimentation and runoff could lead to harmful algal blooms such as toxic red tide (Poloczanska et al. 2009). The potential consequences for harmful algal bloom production and severity, as well as many other potential direct and indirect impacts from severe weather and the effects they could have on the humphead wrasse and its habitat are unknown at this time. While an increase in the frequency and the intensity of storms such as cyclones could impact seagrass, seagrass beds appear remarkably resilient to storm disturbance as long as the plants are not uprooted or heavily smothered. However, if damage or destruction does occur, then re-vegetation can take 10 years or more (Poloczanska et al. 2009).

Summary

There are critical gaps in our knowledge of how climate change will affect tropical marine fishes and their coral reef habitat. Predictions are often based on temperate examples, which may be inappropriate for tropical species. Improved projections of how ocean currents and primary productivity will change are needed to predict more accurately how reef fish population dynamics and connectivity patterns will change. The overall potential and rate for adaptation to climate change also needs more attention (e.g., Munday et al. 2008; Logan et al. 2013).

The extent of potential direct and indirect effects of climate change on the humphead wrasse is unknown or speculative. The threats described in the literature are broad and general, and using another species as a proxy to infer vulnerability of the humphead wrasse is speculative. Branching corals are just one of the many habitats used by post-settlement juvenile and adult humphead wrasse. Adults inhabit coral reefs and typically take advantage of aspects of reef structure for shelter and resting more than relying *per se* on live coral itself. For these reasons, even though humphead wrasse may be affected by climate change impacts to coral reef habitat, the magnitude of impact is unknown at this time.

5.5.4. Pollution

Contaminants such as fuel and crude oil from spills, land-based pollution from agriculture, etc. that find its way into the marine environment, human waste from areas with insufficient sanitation systems, and marine debris from discarded or lost fishing gear are all potential sources of pollution that could directly and indirectly affect the humphead wrasse throughout its entire geographic range.

5.5.4.1. Fuel and crude oil. It is unknown specifically how oil pollution can directly affect humphead wrasse. Documented cases of fuel and oil spills have had impacts ranging from mortality of fish and other marine species to no damage to marine life reported (Loya and Rinkevich 1980). In a laboratory study with rabbit fish (*Siganus rivulatus*), a species native to shallow waters in the Indo-Pacific, the species exhibited a lowering in blood hematocrit values and a pronounced enlargement of the liver when exposed to crude oil and chemical dispersants (Loya and Rinkevich 1980). As for impacts to surrounding habitat, fuel, oil, and emulsifiers can have detrimental effects to reef corals. For example, oil can directly damage coral tissues, decrease a coral colony's viability, and cause excessive mucous secretion leading to enhanced bacterial growth and eventual coral mortality (e.g., Loya and Rinkevich 1980; Peters et al. 1981). Additionally, chemical emulsifiers or detergents that are used to clean up after an oil spill may exacerbate the damage (Loya and Rinkevich 1980). Other reviews from the literature indicate that only severe or prolonged oil pollution has adverse effects to marine species (e.g., Portmann and Connor 1968; Knap et al. 1983; Bak 1987).

5.5.4.2. Land-based pollution. More than 75% of the pollutants entering oceans are from non-point, land-based sources (NOAA 2002 citing U.S. Federal Agencies 1998) and include industrial and agricultural chemicals and sedimentation from development that make their way into the marine environment via terrestrial runoff. This can decrease water quality by increasing turbidity and lowering oxygen levels. It is unknown how land-based pollution effects such as low oxygen levels can specifically impact the humphead wrasse' physiology; however, one study revealed that of 31 reef fish species subjected to hypoxic conditions, most fishes appeared unaffected by hypoxia until the oxygen fell below 10% of air saturation (Nilsson and Östlund-Nilsson 2003).

As for effects to habitat, excessive land-based pollution can degrade and destroy reef, seagrass, and mangrove habitats. The pollution can adversely affect the structure and function of coral reef ecosystems by altering both physical and biological processes. Heavily polluted areas from sources such as sedimentation is associated with fewer coral species, less live coral, lower coral growth rates, reduced coral recruitment, decreased calcification, decreased net productivity of corals, slower rates of reef accretion, increases in both disease prevalence and severity and coral bleaching (Rogers 1990; Edinger et al. 1998; Vega Thurber 2013). However, one study in the Florida Keys revealed that once the injection of pollutants was stopped, the corals were able to make a strong recovery within 10 months (Vega Thurber 2013).

5.5.4.3. Sewage effluent. Impacts from sewage would likely be small and localized considering the species' wide range. Although it is unknown how sewage pollution may directly affect the humphead wrasse' physiology, it is easier to surmise how it would impact the habitat. Nutrient enrichment by sewage effluent may enhance benthic algal biomass and primary production in the water column. Increased primary production in the water column favors benthic filter-feeding invertebrates, but also may out-compete corals and other reef-building organisms (Pastorok and Bilyard 1985). Although no species of fish, coral, invertebrate or algae around treated sewage outfalls exhibited any pathological symptoms (Grigg 1994), untreated sewage and pollution may be a different story. Anthropogenic inputs of dissolved nutrients and organic particulate matter from pollution and untreated sewage may depress oxygen levels. This can result in physiological effects such as metabolic changes, decreased rates of growth and reproduction, as well as decreased coral cover and reduced or inhibited coral recruitment (Pastorok and Bilyard 1985).

5.5.4.4. Marine debris. Marine debris is a ubiquitous threat to marine species. Material discarded from boats and vessels are transported by currents, sometimes long distances, and ocean currents deposit on shallow coral reefs. While direct impacts of marine debris to the humphead wrasse are unknown, there are documented cases of marine species consuming marine debris, which can lead to death, as well as becoming entangled in debris, which too can lead to death. Exotic species attached to drifting marine debris can be transported far from their place of origin and introduced to remote reefs. This may affect everything from fish recruitment to tropic interactions and cause widespread impacts (NOAA 2002).

Summary

Overall, anthropogenic sources of pollution may have deleterious effects to all size classes of humphead wrasse and their habitat. All types of pollution may affect juveniles and adults similarly; however, juveniles would likely be more vulnerable to pollution given their much smaller home ranges than adults. Juvenile habitat (e.g., seagrass beds, mangroves, and inshore reefs) is also more likely to be exposed to contaminants due to their proximity to land, shallowness, and tendency to be more contained (such as a poorly flushed lagoon as opposed to a reef along an open shoreline that is well flushed). However, such events including oil and sewage spills are typically episodic and localized. Other types of pollution such as land-based contaminants and marine debris may also impact the humphead wrasse, but the extent of the effects to the humphead wrasse and its habitat are speculative at this time.

PART II: ASSESSMENT OF EXTINCTION RISK FOR THE HUMPHEAD WRASSE (*CHEILINUS UNDULATUS*)

Photo Credit: Robert Schroeder, NOAA PIFSC CRED

Conducted by the Extinction Risk Analysis (ERA) Team

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6.0. SUMMARY AND CONCLUSIONS FROM THE EXTINCTION RISK ANALYSIS

In order to assess the extinction risk of the humphead wrasse, a team of four NMFS federal fishery biologists was convened. This extinction risk analysis team, henceforth referred to as the "ERA Team," reviewed the best available information in this Status Review document (i.e., from Part I: Biological Assessment and Identification of Threats of *Cheilinus undulatus*) and drew upon their professional knowledge and judgment to evaluate the overall risk of extinction facing the humphead wrasse now and in the foreseeable future. The ERA Team defined "now" as 0-25 years, and defined the "foreseeable future" as 26-50 years (which is similar to time periods defined in other more recent ERA analyses), or, in other words, the timeframe over which threats could be predicted reliably to impact the biological status of the species.

Prior to evaluating the extinction risk of the species, the ERA Team examined the global population of humphead wrasse as described in Part I of this document to see whether any populations qualified as "distinct population segments" (DPSs) under the joint National Marine Fisheries Service and U.S. Fish and Wildlife Service DPS Policy (61 FR 4722; February 7, 1996). Based on the criteria for discreteness and significance under the DPS Policy, delineation of distinct population segments was not supported. Therefore, the global population of the species was subsequently evaluated in terms of its risk of extinction now and in the foreseeable future. Additionally, no population segment was nominated as a "significant portion of the range" (SPOIR) for the species. The outcomes from the DPS, SPOIR, and risk assessments are provided below. Specific details on the methods, definitions of risks, results, and conclusions can be found later in this document.

For the humphead wrasse species as a unit over its entire range, the ERA Team concluded that the demographic factor of abundance had a low-to-moderate likelihood of contributing to the risk of extinction "now" (over 0-25 years) and a moderate-to-high likelihood of contributing to the risk of extinction in the foreseeable future (26-50 years). The quality of abundance data was very poor. The Team gave only a low-to-medium certainty value to knowledge of current abundance and a low certainty to knowledge of abundance in the foreseeable future.

Based on life history parameters, the uncertain information on humphead wrasse productivity was judged to be between that of more productive predatory reef fish, and that of bumphead parrotfish or sharks. The Team found the demographic factor of growth rate and productivity to have a low likelihood now and a moderate likelihood of contributing to the risk of extinction in the foreseeable future. The demographic factors of spatial structure/connectivity had a no-to-low risk both now and the foreseeable future, and diversity had a low risk both now and in the foreseeable future.

Out of the five ESA section 4(a) threat factors, the ERA Team identified only two factors: 1) overutilization for commercial, recreational, scientific, or educational purposes; and 2) the inadequacy of existing regulatory mechanisms as having a moderate likelihood of increasing the extinction risk of the species now. These factors as well as: 3) the present or threatened destruction, or modification, or curtailment of its habitat or range; and 4) other natural or manmade factors affecting its continued existence were observed as having a moderate likelihood of increasing extinction risk in the foreseeable future. The fifth factor, disease or predation was identified as having no, or only small likelihood of increasing extinction risk. Although demographic factors such as abundance and threats such as overutilization were judged moderately likely to increase the species' extinction risk, such judgments qualified the likelihood of increases to extinction risk, not the magnitude of the increased risk. Increments to risk may be likely without being large.

After reviewing the best available information in Part I of the Status Review document, the ERA Team, drawing upon their professional knowledge, integrated the results of the demographic and threats evaluation in a qualitative analysis of the overall risk of extinction, and predicted there was no risk of extinction now for humphead wrasse as a species unit over its entire range. The Team also concluded there was a low overall risk of extinction for the species in the foreseeable future. Again, as NMFS did not support the Team's tentative delineation of a DPS in a core region of the Coral Triangle, and as the Team determined that no SPOIR existed, the extinction risk analysis was done for the species throughout its range.

7.0. INTRODUCTION

The Endangered Species Act (ESA) (Section 3) defines endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range." Threatened species is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Neither the National Marine Fisheries Service (NMFS) nor the U.S. Fish and Wildlife Service (USFWS) have developed any formal policy guidance about how to interpret the definitions of "threatened" or "endangered" species in the ESA. In many previous NMFS status reviews, a team has been convened, often referred to as a "Biological Review Team," in order to compile the best available information on the species and conduct a risk assessment through evaluation of the demographic risks, threats, and extinction risk facing the species or distinct population segment (DPS). This information is ultimately used by the NMFS Protected Resources Division, after consideration of the legal and policy dimensions of the ESA standards and benefits of ongoing conservation efforts, to make a listing determination. For purposes of this risk assessment, an Extinction Risk Assessment (ERA) Team comprising NMFS federal fishery biologists was convened. The ERA Team was tasked to review information compiled in "Part I: Biological Assessment and Identification of Threats of the Humphead Wrasse" of this Status Review document. Following review of this information, the ERA Team was asked to conduct a DPS analysis, evaluate whether there exists an area that is smaller than the entire range of the species that can be considered a significant portion of the species' range (SPOIR), and evaluate the overall risk of extinction facing the humphead wrasse now and in the foreseeable future.

8.0. DISTINCT POPULATION SEGMENT ANALYSIS

8.1. Consideration of the Species Question

In determining whether to list a species, the first issue is whether the petitioned subject is a valid species. The petitioned subject, the humphead wrasse, or *Cheilinus undulatus* (Rüppel, 1835), is a valid species for listing. The taxonomic breakdown of *C. undulatus* is as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Perciformes
Family: Labridae
Genus: *Cheilinus*
Species: *undulatus*

8.2. Criteria for Identification of Distinct Population Segments

After determining whether the petition identifies a species, the Team considered whether any populations qualify as DPSs within the species. The DPS Policy provides guidelines for defining DPSs below the taxonomic level of species (61 FR 4722; February 7, 1996). The policy identifies two elements to consider in a decision regarding whether a population qualifies as a DPS: discreteness of the population segment in relation to the remainder of the species to which it belongs; and the significance of the population segment to the species to which it belongs.

<u>Discreteness</u>
Per the DPS Policy, a DPS may be considered discrete if it is (1) markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation; or if (2) it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.

<u>Significance</u>
If a population segment is considered discrete, its biological and ecological significance must then be evaluated. Significance is evaluated in terms of the importance of the population segment to the overall welfare of the species. Some of the considerations that can be used to determine a discrete population segment's significance to the taxon as a whole include, but are not limited to:

1) Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon;
2) Evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon;
3) Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range; or
4) Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

As stated in the DPS Policy, Congress expressed its expectation that the Services would exercise authority with regard to DPSs "sparingly" and only when the biological evidence indicates such action is warranted.

The best available information must be used in determining that a population meets the DPS Policy criteria. At the same time, the DPS Policy allows for flexibility in identifying DPSs. DPSs need not be identified at the lowest level of distinction possible, especially if this will not provide a conservation benefit to the species.

DPS Methods

The Team decided to evaluate the information regarding the "discreteness" and "significance" criteria through a voting process. That process and results are provided in detail in Appendix I and Table 17.

8.3. Conclusions for Distinct Population Segment Determination

The petitioners did not request that the humphead wrasse be divided into DPSs for the purposes of listing under the ESA. Nevertheless, the humphead wrasse ERA Team Terms of Reference specifically charged the Team with evaluating whether any populations of the humphead wrasse qualify as DPSs. Consequently, the Team reviewed the applicable information and agreed that a DPS analysis merited consideration, largely due to the importance of the international boundaries containing three countries at the core of the "Coral Triangle" region that have been the significant exporters of humphead wrasse for the live reef fish food trade (LRFFT). These countries are Indonesia, Malaysia, and the Philippines (Sadovy et al. 2003a; CITES 2010b; Sadovy de Mitcheson et al. 2010; Sadovy et al. 2011) and the humphead wrasse within these international boundaries were proposed as the "core-Coral Triangle" (core-CT) DPS. By default, in order to account for the remainder of the humphead wrasse population, the rest of the global population would also constitute a DPS, tentatively referred to as the "Indo-Pacific DPS," in order to consider the whole of the taxon in any analysis. However, since the "core-CT DPS" was the source of discussion and voting, only arguments for the tentative "core-CT DPS" are presented below.

As the DPS Policy (61 FR 4722) indicates, "The inclusion of international boundaries in determining whether a population segment is discrete is sometimes undertaken as a matter of policy rather than science." Based on this guidance, the ERA Team should not establish the discreteness of a DPS *solely* due to being delimited by international boundaries without a supporting decision from NMFS. The Team conducted this DPS analysis for such consideration and the results are presented in Appendix I to show that no biological basis was found for discreteness, but that international boundaries might define a DPS that was significant with regard to ecological setting and recovery *if* discreteness was considered valid as a matter of policy rather than science.

After consideration of the Act and the DPS Policy, NMFS does not support the Team's tentative delineation of any DPSs for the humphead wrasse for the following reasons. The ERA team found support for discreteness of the humphead wrasse population within the core-CT area based on being delimited by international governmental boundaries within which regulation and governance of threats is significantly different from other portions of the species' range. However, the Team found no biological basis (no morphological, behavioral, genetic, etc., basis) to support this discreteness determination (see Appendix I). Congress specifically instructed the Services to exercise their authority to list DPSs "…sparingly and only when the biological evidence indicates that such action is warranted." In addition, because the core-Coral Triangle area is entirely international with no U.S. governance, delineation of a DPS within this area would not provide a conservation benefit to the species. Therefore, NMFS did not support the delineation of the humphead wrasse population within the core-CT area as a DPS, and there was no evidence of any other DPSs within the species' range. Following this decision, the ERA Team was asked by NMFS to conduct the extinction risk analysis on the entire global population of the humphead wrasse.

Despite this decision based on the aforementioned reasons, to be as transparent as possible, the Team's arguments and votes for and against both discreteness and significance of a possible core-CT DPS are described in Appendix A.

9.0. SIGNIFICANT PORTION OF ITS RANGE ANALYSIS

As noted in the Introduction section above, the definitions of both "threatened" and "endangered" under the ESA contain the term "significant portion of its range" (SPOIR). The phrase has never been formally interpreted by NMFS. In 2011, NMFS and FWS published a draft policy on interpretation of the phrase (76 FR 76987; December 9, 2011) and although this policy was recently finalized on July 1, 2014 (79 FR 37578), it remained in draft form when the ERA Team was conducting their SPOIR analysis as part of the extinction risk analysis. Using the Draft Policy, we were asked to consider the interpretations and principles contained in the Draft Policy with regards to the humphead wrasse as non-binding guidance. Specifically, we were asked to identify any SPOIRs for the humphead wrasse with the understanding that a portion of the range of a species is "significant" if its contribution to the viability of the species is so important that, without that portion, the species might not survive.

9.1. SPOIR Conclusion

The Team considered the primary region that exhibited decline of the humphead wrasse, which comprises the three countries at the core of the “coral triangle” area, as a potential SPOIR. These countries are Indonesia, Malaysia, and the Philippines, which have large and growing human populations with coincident agricultural expansion and coastal development impacts on humphead wrasse habitat. In its DPS analysis, the Team discussed physical, ecological, and behavioral factors in relation to recruitment across boundaries and concluded that local extirpation of the population in these three countries would not create a permanent gap in the species’ range, and that recruitment from less impacted peripheral humphead wrasse populations could recolonize this portion of the range if exploitation there were controlled. Given the possibility that exploitation could be controlled, however long such a gap might exist, the gap could not be considered permanent. The status of the rest of the species was not considered to be dependent on the continued existence of the population in these three countries. That is because reproductive behavior and juveniles are observed throughout much of the species range, so there is no reason to suppose recruitment depends primarily on larval or juvenile transport from the potential SPOIR. The main purpose for improved conservation in this core area of the species’ range would be the recovery of the local populations there, and not the status of the rest of the species. Thus, under the Draft Policy, no area or population segment within an area was nominated as a “significant portion of its range” (SPOIR) for the species.

10.0. EXTINCTION RISK ANALYSIS

Often the ability to measure or document risk factors is limited, and information is not quantitative and very often lacking altogether. Therefore, in assessing risk, it is important to include both qualitative and quantitative information. In previous NMFS status reviews, Biological Review Teams have used a risk matrix method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainright and Kope (1999) and has been used in Pacific salmonid status reviews as well as in reviews of Pacific hake, walleye pollock, Pacific cod, Puget Sound rockfishes, Pacific herring, and black abalone, among others (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). In the risk matrix approach, the collective condition of the species is summarized on a global level according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity. These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. Using these concepts, the ERA Team estimated the extinction risk of the humphead wrasse after conducting a demographic risks analysis. Likewise, the ERA Team performed a threats assessment by scoring the severity of threats to the species now as well as in the foreseeable future. The summary of the demographic risks and threats obtained by this approach was then considered by the ERA Team in determining the species’ overall level of extinction risk. Specifics on each analysis are provided below.

10.1. Defining Now and the Foreseeable Future

For the purpose of this extinction risk analysis, "now" is defined as the current timeframe forward from which conditions should resemble those at present, and chose this timeframe to be from present day out to 4 generations of the species, or 0-25 years. Given uncertainty and other possible generation times, the Team would still define the current time frame as 0-25 years. And for the purpose of this extinction risk analysis, the term "foreseeable future" was defined as the future timeframe over which demographic risks and threats can be "reliably" predicted to impact the biological status of the humphead wrasse. Due to data limitations, the Team used professional judgment (rather than quantitative modeling) when making forecasts, so reliability was judged to be subjective for this timeframe. The Team defined "foreseeable future" as another 5 to 8 generations of the species, or 26-50 years. Again, given uncertainty and other possible generation times, the team would still use this time frame for the "foreseeable future."

Many aspects of life history are pertinent to the extinction risk of the humphead wrasse. Similar to many large-bodied species, the humphead wrasse is: slow growing; long-lived; delayed reproductive development (Choat et al. 2006; Tupper 2007; Sadovy de Mitcheson et al. 2008; Colin 2010); and the vulnerability of this species is exacerbated by other factors such as its home ranging behavior; predictable sleeping sites; and discrete, resident spawning locations and the formation of mass aggregations during spawning (Sadovy et al. 2003a). The minimum population doubling time or generation time, which is defined as the time it takes, on average, for a sexually mature female humphead wrasse to be replaced by offspring with the same spawning capacity, is estimated to take 4.5 to 14 years (Fishbase.org). Choat et al. (2006) was chosen as the most authoritative reference and lists 6-7 years for age at first maturity of females. Therefore, for convenience and to avoid a false sense of certainty, the Team assumed 6-7 years for generation time in its consideration of "now" as equivalent to the next 25 years, and the "foreseeable future" as equivalent to 26-50 years in the future.

Considering all of this, and taking into account the longevity of the species, the Team agreed that it would likely take several generation times for any conservative management action to be realized and reflected in population abundance. The Team also agreed it could, with some background knowledge and expert opinion regarding demography and exploitation, project threats out to 26-50 years and project the impact of these threats on the biological status of the species within this timeframe.

10.2. Qualitative Risk Analysis Methods

10.2.1. Demographic Risk Analysis

The ERA Team reviewed relevant biological and commercial information for the species, including: current abundance or density of the species, current abundance or density in relation to historical abundance/density and trends in abundance/density, its spatial and temporal distribution, spatial structure and connectivity, natural and human-influenced factors that cause variability in survival and abundance/density including growth rate and productivity, and diversity. It was not possible to consider any specific threats to genetic integrity, as there is no knowledge of the species' genetics. Following this review, which is summarized in the results

(Section 11.0), each ERA Team member independently assigned a risk score of either 1, 2, 3, 4, or 5 to each of the four demographic criteria (abundance, growth rate/productivity, spatial structure/connectivity, and diversity), for both now and in the foreseeable future. Risks for each demographic criterion were ranked on a scale of 1 (no risk) to 5 (very high risk). Below are the definitions that the Team used for each ranking:

1 = No risk: This factor does not contribute significantly to risk of extinction.

2 = Low risk: It is unlikely that this factor contributes significantly to risk of extinction.

3 = Moderate risk: It is moderately likely that this factor contributes significantly to risk of extinction.

4 = High risk: It is highly likely that this factor contributes significantly to risk of extinction.

5 = Very high risk: It is almost certain that this factor contributes significantly to risk of extinction.

The Team members also expressed their certainty regarding evidence of risk using a ranking of low, medium, and high (a mean certainty value of 1.0 or 1.25 indicated an overall low certainty by the Team, whereas 1.5 to 2.0 indicated a medium certainty, and 2.25 or higher indicated a high certainty).

The Team members were given a template to fill out and asked to rank the risk of the demographic factors, using a score of 1, 2, 3, 4, or 5, for the humphead wrasse, both within 0-25 years ("now") and in 26-50 years from present day ("foreseeable future"). After scores were provided, the Team was given time to discuss or reconsider the range of perspectives for each of the demographic risks and the supporting data on which it was based, and was given the opportunity to revise scores if desired. The scores for all Team members were tallied (range and mean) for each of the four demographic factors and considered by the Team in making the overall risk determination. Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk, so overall risk was evaluated in a separate process following the demographic and threats analysis.

10.2.2. Threats Assessment

Section 4(a)(1) of the ESA requires the agency to determine whether the species is endangered or threatened because of any of the following factors:

A) The present or threatened destruction, modification or curtailment of its habitat or range;
B) Overutilization for commercial, recreational, scientific, or educational purposes;
C) Disease or predation;
D) The inadequacy of existing regulatory mechanisms; or
E) Other natural or manmade factors affecting its continued existence.

The ERA Team reviewed relevant biological and commercial information for the species regarding these threats and the relevant sub-threats (Table 15). This review is summarized in the results of the threats analysis (Section 11.0). Similar to the demographics risk analysis, the ERA Team members were given a template to fill out and asked to rank the effect that the threat was having on the extinction risk of the species now and may have in the foreseeable future. Below are the specific definitions of the threat effect levels:

> No effect on extinction risk: This threat has no effect on the species' extinction risk.
>
> Small effect: It is unlikely that this threat is increasing the species' extinction risk.
>
> Moderate effect: It is moderately likely that this threat is increasing the species' extinction risk.
> Significant effect: It is highly likely that this threat poses a significant risk to the species' continued existence.

As with the demographic risk analysis, the Team members also expressed their certainty in a ranking of low, medium, and high (a mean certainty value of 1.0 or 1.25 indicated an overall low certainty by the Team, whereas 1.5 to 2.0 indicated a medium certainty, and 2.25 or higher indicated a high certainty).

To allow individuals to express a distribution of risk scores in assessing the impacts of the threats to the species, the ERA Team adopted the "likelihood point" (FEMAT) method used in previous status reviews (e.g., Pacific salmon, Puget Sound Rockfish, Pacific herring, black abalone, great hammerhead shark) to structure the Team's thinking and express levels of risk as a distribution in assigning threat risk categories. Since four threat effect levels were defined by the Team, 8 likelihood points were distributed per team member among the four threat effect levels (e.g., no, small, moderate, and significant) for each threat factor and sub-factor (i.e., the section 4(a)(1) factors [A-E]; Table 13). The team followed recent status reviews in not using the likelihood point approach for the demographic risk analysis (above). The Team conceived of the likelihood point distribution as an indication of the breadth of possibilities indicated by information on each threat, and although this dispersion is indicative of variation in results, the Team was enthusiastic about also qualifying its analysis with an explicit statement regarding their certainty based on the quality of the available information. After scores were provided, the Team was given the opportunity to discuss or reconsider the evidence and revise scores if desired. The scores were then tallied (mean and range for certainty, and frequency, range, mode, and median for likelihood points), reviewed by the ERA Team, and considered in making the overall risk determination.

Table 13.--List of 13 sub-factor threats that made up each of the five section 4(a) factors [A-E] (see Part I of the Status Review document for more information). This was used to determine overall risk during ERA Team deliberations.

THREAT	Destructive fishing practices	Loss/modification of juvenile nursery areas	Loss/modification of adult habitat	Artisanal fisheries	Commercial fisheries (i.e., LRFFT, aquaculture/mariculture)	Overexploitation of spawning sites	IUU fishing	Disease or predation	Inadequacy of existing regulatory mechanisms	Life history characteristics	Competition	Climate change	Pollution
ESA Section 4(a)(1) Factor	(A) Habitat destruction, modification or curtailment			(B) Overutilization for commercial, recreational, scientific or education purposes				(C) Disease or predation	(D) Inadequacy of existing regulatory mechanisms	(E) Other natural or manmade factors			

10.2.3. Overall Level of Extinction Risk Analysis

Guided by the results from the risk analysis of demographic factors (abundance, growth rate and productivity, spatial structure/connectivity, and diversity) as well as the threats assessment, the ERA Team members used their informed professional judgment to make an overall extinction risk determination for the humphead wrasse now (over the next 0-25 years) and in the foreseeable future (over the next 26-50 years). For these analyses, the ERA Team defined five levels of overall extinction risk:

> 1 = No risk: This species is not at risk of extinction due to projected (known or potential) threats or demographic factors.
>
> 2 = Low risk: It is unlikely that this species is at risk of extinction due to trends in demographic factors. Threats may alter those trends but not enough to cause risk due to stochastic or depensatory processes.
>
> 3 = Moderate risk: The species may be at moderate risk of extinction due to declining demographic factors and threats that inhibit the reversal of these trends.
>
> 4 = High risk: Demographic factors and threats place the species' persistence in question.
>
> 5 = Very high risk: The species is strongly at risk from stochastic or depensatory processes, and is facing threats exacerbating the demographic factors, indicating imminent extinction.

The Team members also expressed their certainty in a ranking of low, medium, and high (a mean certainty value of 1.0 or 1.25 indicated an overall low certainty by the Team, whereas 1.5 to 2.0 indicated a medium certainty, and 2.25 or higher indicated a high certainty). Similar to the voting process for the threats analysis, the Team adopted the FEMAT method and 10 likelihood points per team member were distributed among the five levels of extinction risk. The scores were then tallied (mean and range for certainty, and frequency, range, mode, and median for likelihood points), discussed, and summarized for the species.

Finally, the ERA Team drew scientific conclusions about the overall risk of extinction faced by the species under present conditions and in the foreseeable future based on an evaluation of the species' demographic risks and assessment of threats. The ERA Team did not make recommendations as to whether the species should be listed as threatened or endangered, or if it did not warrant listing.

10.3. Quantitative Risk Analysis

A quantitative population viability analysis was not conducted for humphead wrasse because of either the complete lack or inadequacy of data on population size, trends in population size or apparent abundance, intrinsic rate of increase, mortality rates, or size structure. Although inferences could be made about natural mortality and intrinsic productivity from growth rate and maximum size data, data on exploitation rate, populations sizes, trends, and population dynamics are so lacking as to make the assumptions required for such modeling no better than the Team's general opinion of the population's demographic status, which was qualitatively reviewed (below).

11.0. EXTINCTION RISK RESULTS AND CONCLUSIONS FOR THE HUMPHEAD WRASSE

11.1. Evaluation of Demographic Risks

The following table (Table 14) gives the results of the ERA Team's evaluation of demographic risks to the humphead wrasse. Scores were tallied and the summary information is presented below.

Table 14.--Demographic risk matrix used in ERA Team deliberations. The matrix is divided into four sections that correspond to the parameters for assessing population viability. (Source: McElhany et al. 2000)

Abundance				
	NOW		**FORESEEABLE FUTURE**	
Team Member	**Risk**	**Certainty Ranking**	**Risk**	**Certainty Ranking**
A	3	1	4	1
B	2	2	3	1
C	3	1	4	1
D	2	2	3	1
Range	2 to 3	L to M	3 to 4	L
Mean	**2.5**	**Medium**	**3.5**	**Low**
Risk Score	**Low-moderate**		**Moderate-high**	

Table 14 *continued*

Growth rate and productivity				
	NOW		FORESEEABLE FUTURE	
Team Member	**Risk**	**Certainty Ranking**	**Risk**	**Certainty Ranking**
A	2	1	3	1
B	2	2	3	1
C	3	2	3	1
D	2	2	3	1
Range	2 to 3	L to M	3	Low
Mean	**2.25**	**Medium**	**3**	**Low**
Risk Score	**Low**		**Moderate**	

Spatial structure and connectivity				
	NOW		FORESEEABLE FUTURE	
Team Member	**Risk**	**Certainty Ranking**	**Risk**	**Certainty Ranking**
A	2	1	2	1
B	2	2	2	2
C	1	1	1	1
D	2	1	2	1
Range	1 to 2	L to M	1 to 2	L to M
Mean	**1.75**	**Low**	**1.75**	**Low**
Risk Score	**No-low**		**No-low**	

Diversity				
	NOW		FORESEEABLE FUTURE	
Team Member	**Risk**	**Certainty Ranking**	**Risk**	**Certainty Ranking**
A	2	1	2	1
B	2	1	2	1
C	2	1	2	1
D	2	1	2	1
Range	2	L	2	L
Mean	**2**	**Low**	**2**	**Low**
Risk Score	**Low**		**Low**	

Abundance

ERA Team scores for the demographic risk related to the abundance of the humphead wrasse "now" (0-25 year timeframe) ranged from 2 to 3, with a mean score of 2.5 (Table 16). A score of 2.5 represents a low to moderate risk, meaning that it is unlikely to moderately likely that this factor contributes significantly to risk of extinction. For the foreseeable future (26-50 years), Team scores for demographic risk related to the abundance of the humphead wrasse ranged higher, from 3 to 4 with a mean score of 3.5 meaning that it is moderately to highly likely that this factor contributes significantly to risk of extinction. This was the highest demographic risk determined by the ERA Team; risk was found to be higher in the foreseeable future than now simply because the increased chance that declines in abundance, if they are occurring throughout the species' range (uncertain), may become more serious with the passage of time, unless regulations are effective and enforced. The Team's consensus was that certainty was medium (now) and low (for the foreseeable future) regarding the information available to analyze demographic risk associated with abundance. The following points were influential in the Teams conclusions:

Currently, there are no formal estimates of population size throughout most of the humphead wrasses' range. It is known that this species is uncommon to rare throughout most of its range, in some cases exhibiting low abundance in areas where no anthropogenic stressors are evident. In the Commonwealth of the Northern Mariana Islands, for example, humphead wrasses appear to be more prevalent in the southern populated islands, as compared to the mostly uninhabited, or lightly populated islands north of Saipan. In this case, there exist several factors that influence humphead wrasse abundance such as total habitat availability, fishing access to humphead wrasse due to island size and/or orientation, and restrictions on fishing effort. Low levels of abundance, whether natural or anthropogenically influenced, could pose significant risk to the species in combination with other factors, such as overutilization, since a species that is already at naturally low levels may not be able to withstand heavy fishing pressure, in particular at the adult stage where natural mortality is lowest.

Presently, there is insufficient data on abundance and size to indicate whether or not depensatory processes are at work. Small individuals have been observed in some heavily fished areas (Table 3, Figure 6). The available indicators of abundance are hampered by the observation error inherent in the variety of methodologies used in fishery independent surveys—methodologies which in many cases are not adequately described and thus not easily duplicated in subsequent surveys (though the use of a global positioning system (GPS) and aerial photographs to log exact locations in more recent surveys [such as Colin 2010] is now useful for resurveys). The low natural occurrence of this species on coral reefs requires that observational surveys be designed specifically for juvenile and adult humphead wrasse, as habitat requirements of those life history stages vary.

Noted changes in abundance appear to be restricted to particular areas where the LRFFT has been active for several decades. In some areas where no apparent harvest occurs, the species has not demonstrated any notable changes between surveys. One aspect lacking in many fishery-independent surveys is meaningful time series of observations incorporating standardized methodological protocols. Without such time series, drawing firm conclusions based on temporally and/or spatially distinct observations is simply not possible. In addition, surveyed locations (i.e., exact locations, habitat type, water depth) and methods (i.e., stationary point count, towed-diver surveys) are an important descriptor in survey work, as not all areas where the humphead wrasse exists are equally accessible for underwater visual census surveys. In other words, survey results across different locations and time frames are hard to compare.

Existing information (Table 3) suggests that humphead wrasse populations are most abundant and stable in the Indian Ocean (including the Timor Sea), while populations in the core-CT area appear depressed except possibly in a few areas in Malaysia (e.g., West of Sabah, Pulau Sipadan, and Hoga Island in Wakatobi Marine National Park; see Table 3) where either military or management protection exists (IUCN 2008 citing TRACC 2004). These "pockets" of abundance in the core-CT area may be important potential source populations to other core-CT populations. However, density estimates from these areas with increased abundance are at least a decade old, and no recent information is available to indicate that these densities have remained stable, although there is no reason to expect otherwise, especially in designated military bases, where access is assumed to be extremely limited. There are many other areas where the species has been protected by fishing regulations or reserves, including both foreign and domestic jurisdictions (Tables 12 and 13), and the species continues to be observed throughout the Pacific wherever surveyed.

As previously noted (Table 2), it is certain that humphead wrasse have declined in some areas due to overfishing. Recent relative abundance data included in Part I of the Status Review document suggest that many populations, especially those in U.S. waters (Tables 4-7) are either stable, show no clear trend, or may be increasing. Conversely, in the core-CT area, harvest has been significant near human population centers (and to some extent more remote locations that can be accessed via vessel), and fish populations appear to remain depressed to a degree that is not quantifiable. This continued depression of abundance in core-CT areas that have been heavily exploited presents the most appreciable demographic risk considered by the ERA Team.

Growth Rate and Productivity

The ERA Team had no information for this factor that was not derived from life history characteristics of the species. The Team's scores for the demographic risk related to the growth rate and productivity of the humphead wrasse "now" (0-25 year timeframe) ranged from 2 to 3, with a mean score of 2.25 tending more towards low risk (with one opinion of moderate risk) that this factor contributes significantly to risk of extinction (Table 14). For the foreseeable future (26-50 years), Team scores for demographic risk related to growth rate and productivity were unanimous at the value of 3, meaning that it is moderately likely that this factor contributes significantly to risk of extinction. The higher assigned value of risk for the foreseeable future was simply due to uncertainty and the greater risk due to continuing low productivity with the further passage of time. This was reflected by the Team's consensus that certainty was medium (now) and low (foreseeable future) regarding the information available to analyze demographic risk associated with growth rate and productivity. As a large-bodied and naturally uncommon/rare carnivore, the humphead wrasse is fairly long-lived (at 30 years), based on the only existing published information, for a single region: Australia's Great Barrier Reef (GBR). It is presently unknown whether its longevity on the GBR is typical of the species throughout its broad geographic range. It is generally slow-growing as an adult; however, growth rates prior to maturity are rather fast: age-at-first sexual maturity is about 6-7 years, corresponding to body lengths of 45-50 cm for females; and 9 years, corresponding to 70 cm for males (Choat et al. 2006, Table 1). The oldest, but not largest, documented individuals are female and some females never change sex. Like a number of other protogynous fishes, growth rates accelerate after females change sex to males. On balance, the growth rate of this wrasse on the GBR lies towards the slow end of the slow-to-fast growth continuum of reef fishes: some species grow more slowly and many others grow faster. The Team recognized that being towards the slow end of the continuum in and of itself creates some extinction risk compared with fish that grow faster.

There are no direct independent estimates of the productivity of this wrasse, so its productivity must be deduced from growth and reproductive output. Estimated size-at-age and longevity of wrasse on the GBR based on conventional growth band counting on cross-sectioned otoliths (sagittae) has recently been validated using bomb-carbon dating (Andrews et al. submitted). The von Bertalanffy (VBGF) growth coefficient (k) has not been estimated for GBR populations of wrasse, but its annual total mortality rate on the GBR is $0.11\text{-}0.14 \cdot yr^{-1}$. Although fecundity and egg production have not been estimated for this wrasse, if it is like other tropical wrasses, it likely spawns multiple batches of small (< 1 mm diameter) eggs over sequential, protracted spawning seasons.

For comparison, the Team reviewed data on other species recently subject to ERA analysis. Compared to relatively longer-lived, later-maturing, and lower-fecundity elasmobranch fishes like the great hammerhead shark this wrasse is a more r-selected species. The great hammerhead shark lives to > 40 years, has a median age-at- maturity (generation time) of 14-18 years, and live-bears only a single litter of 6-42, 50-70 cm-long pups once every 2 years. A congener of the great hammerhead shark, the scalloped hammerhead shark, has a comparably slow growth rate (VBGF k < 0.1), age-at-maturity (generally 7-15 years), longevity (20-30 years), and live-bears a litter of 3-41, 40-60 cm-long pups every 1-2 years. Vital rates of the wrasse are slightly more r-selected than those of bumphead parrotfish, a more closely related scarine labrid bony fish: VBGF k = 0.1-0.136 yr^{-1}, 55-65 cm TL length-at-maturity corresponding to an age-at-maturity of 7-9 years, and 40+ year longevity. The intrinsic rate of increase of 0,72 derived from life history parameters (Fishbase.org) indicated that humphead wrasse was on the higher end of the productivity scale, but not as productive as some other exploited predatory reef fish. The Team judged the wrasse's productivity to be between that of more productive predatory reef fish, and the less productive bumphead parrotfish and sharks.

Spatial Structure/Connectivity, and Diversity

Team scores for demographic risk related to the spatial structure and connectivity of the humphead wrasse now (0-25 year time frame) ranged from 1 (one opinion) to primarily 2 (low risk) with a mean of 1.75 meaning that it is unlikely that this factor contributes significantly to risk of extinction (Table 14). The exact same scores resulted for the foreseeable future (26-50 years). The demographic risks associated with diversity were rated very similarly to the closely related factors of spatial structure and connectivity, with the risk level voted unanimously as 2 for both time periods, meaning it is unlikely that diversity contributes significantly to risk of extinction. In all cases, the Team's consensus was that certainty was low regarding the information available to analyze demographic risk associated with spatial structure/connectivity and with diversity. The following points were influential in the Teams conclusions:

1) This factor includes consideration of the geographic distribution of individuals in the populations and the processes that create and maintain this structure. This depends on dispersal dynamics of individuals as well as habitat quality and existing spatial structure. Diversity relates primarily to genetic factors, within and/or among populations. Connectivity is through spawning and planktonic larval dispersal processes. Spatial structure and diversity are important as they potentially allow the species to survive in more diverse environments, and enable it to positively respond to, and survive, long-term environmental changes.

2) The humphead wrasse is known to occur in waters around 48 countries, from the Red Sea, east through the tropical Indian and Pacific Oceans, to French Polynesia. This geography includes tens-of-thousands of islands with diverse and varying bathymetry (e.g., shallow coral reefs) along mainland coasts, most within close proximity and (presumed) easy dispersal reach of pelagic larvae of this species (high connectivity).

3) Essentially nothing is currently known regarding the spatial structure and (genetic) diversity of the humphead wrasse. Conclusive studies on spatial structure at localized scales are not available. It is also not known if there are any manmade or ecological factors that could significantly alter gene flow in the species. It is not known if the humphead wrasse consists of more than one population throughout its range or if any genetically distinct populations exist. Without definitive genetic information, the Team assumes that the species does not appear to be at risk of a genetic bottleneck, meaning that the humphead wrasse is likely able to adapt overtime to changing environments. The Team concluded that while data are either completely lacking, or inadequate, it can be reasonably presumed that, across its entire range, the characteristics of spatial structure/connectivity and genetic diversity, by themselves, are unlikely to contribute to an extinction risk for the humphead wrasse, both now and in the foreseeable future.

11.2. Threats Assessment

The following table (Table 15) gives results of the ERA Team's analysis of the effect of threats to the humphead wrasse. Likelihood points were tallied and the summary information is presented for each ESA section 4(a)(1) factor.

Table 15.--Humphead wrasse threats assessment used in ERA Team deliberations using 8 likelihood points per team member. Threats evaluated at the global population level (consistent with DPS determination).

	NOW					FORESEEABLE FUTURE				
Threat (and Factor letter)	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**
Habitat destruction, modification or curtailment (A)	1	4	2	1	2	1	2	4	1	1
	1	3	2	2	2	1	2	2	3	2
	0	6	2	0	2	0	3	3	2	2
	0	4	3	1	2	0	3	3	2	1
MEAN					**Medium (2)**					**Medium (1.5)**
FREQUENCY	2	**17**	9	4		2	10	**12**	8	
RANGE	**********	*********	***********	***********	M	**********	*******	**********	***********	L to M
MODE		**Small**						**Moderate**		
MEDIAN		**Small**						**Moderate**		

	NOW					FORESEEABLE FUTURE				
Threat (and Factor letter)	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**
Overutilization (B)	1	2	4	1	2	0	1	5	2	1
	1	3	3	1	2	1	3	3	1	2
	0	5	2	1	2	0	2	4	2	1
	0	3	4	1	2	0	4	3	1	1
MEAN					**Medium (2)**					**Low (1.25)**
FREQUENCY	2	**13**	**13**	4		1	10	**15**	6	
RANGE	**********	********	***********	***********	M	**********	********	**********	***********	L to M
MODE		**Small**	**Moderate**					**Moderate**		
MEDIAN		**Small**	**Moderate**					**Moderate**		

Table 15 *continued*

	NOW					FORESEEABLE FUTURE				
Threat (and Factor letter)	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**
Disease or predation (C)	2	4	2	0	1	2	5	1	0	2
	4	3	1	0	2	4	3	1	0	2
	0	8	0	0	2	0	7	1	0	2
	5	3	0	0	3	6	2	0	0	2
MEAN					**Medium (2)**					**Medium (2)**
FREQUENCY	11	**18**	3	0		12	**17**	3	0	
RANGE	**********	********	***********		L to H	**********	********	**********		M
MODE		**Small**					**Small**			
MEDIAN		**Small**					**Small**			

	NOW					FORESEEABLE FUTURE				
Threat (and Factor letter)	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**
Inadequacy of existing regulatory mechanisms (D)	1	2	4	1	2	1	3	3	1	1
	4	1	2	1	2	1	3	3	1	2
	0	4	3	1	1	0	1	4	3	1
	0	3	4	1	2	0	4	3	1	1
MEAN					**Medium (1.75)**					**Low (1.25)**
FREQUENCY	5	10	**13**	4		2	11	**13**	6	
RANGE	**********	********	***********	***********	L to M	**********	********	**********	**********	L to M
MODE			**Moderate**					**Moderate**		
MEDIAN			**Moderate**					**Moderate**		

Table 15 *continued*

	NOW					FORESEEABLE FUTURE				
Threat (and Factor letter)	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**	**No effect**	**Small**	**Moderate**	**Significant**	**Certainty**
Other (E)	1	3	3	1	2	2	2	2	2	1
	1	4	2	1	2	1	2	3	2	1
	0	5	2	1	2	0	1	5	2	1
	2	3	3	0	2	0	3	4	1	1
MEAN					**Medium (2)**					**Low (1)**
FREQUENCY	4	**15**	10	3		3	8	**14**	7	
RANGE	**********	********	***********	***********	M	**********	********	**********	*************	L
MODE		**Small**						**Moderate**		
MEDIAN		**Small**						**Moderate**		

Out of the five ESA section 4(a)(1) factors, the Team identified overutilization and inadequacy of existing regulatory mechanisms as having moderate likelihood of increasing the extinction risk of the species now (over 0-25 years). These as well as habitat factors and other natural or manmade factors were observed as having moderate likelihood of increasing extinction risk in the foreseeable future (26-50 years), whereas the other factors were identified as having only small effects on extinction risk. Certainty was judged to be medium for the information available on all effects and timeframes except for overutilization, inadequacy of existing regulations, and other natural or manmade factors in the foreseeable future. Below is a brief discussion of the rationale for the ERA Team's conclusions regarding the threats assessment.

Habitat Destruction, Modification, or Curtailment

With regard to destructive fishing practices, cyanide fishing is the major practice that is used to target this wrasse, although a relatively small number of (mostly small-sized) fish of this species might occasionally be killed incidentally during dynamite (blast) fishing for other reef fishes in open-reef environments. Other reef-destructive fishing methods such as muro-ami (drive-fishing) are probably of even less relevance to this wrasse. The intent in using cyanide is to stun (not kill) juvenile wrasse and capture them alive for subsequent grow-out for sale in the LRFFT; however, some and perhaps a substantial proportion of cyanide-fished wrasse die prior to actually contributing product to the industry. Much of the current LRFFT for wrasse involves cyanide fishing of juveniles for pen-culture grow-out before shipment to market; and the cyanide fishing of juveniles is likely to increase disproportionately as adult stocks become locally or regionally extirpated to greater extents. Cyanide fishing is still a major fishing method in Southeast Asia (primarily in the Philippines and secondarily in Indonesia), but cyanide fishing is presently much less of a concern throughout the rest of the Indo-Pacific region (Sadovy de Mitcheson and Yin, in press), and thus of less concern to the species throughout its range. In addition to its deleterious effects on humphead wrasse, the cyanide released into and near the reef substrate has substantial acute (mortality) and delayed health (morbidity) effects on other fishes in and near the reef and on the non-fish motile, sessile, and other biota including corals.

Regarding the loss and modification of juvenile nursery areas, burgeoning coastal development and poor land management (e.g., sedimentation) in developing tropical third world countries appears to be the major threat to the seagrass and branching coral and macroalgal habitats that provide juvenile nursery habitat. The cutting of mangroves for firewood used to fuel open-fire cooking stoves is another increasing problem reflecting exponential human population growth in many of these developing countries. Approximately one-third of all mangroves worldwide have been lost in the past 50 years.

Regarding the loss and modification of adult habitat, the major threats to the primary habitat (forereef and open-lagoons) appear to be climate change-induced coral bleaching and acidification, both of which are undoubtedly impacting corals (especially resulting from loss of zooxanthellae symbionts) and other organisms with carbonate skeletons. Additionally, increased storm activity and wave events are also major factors in altering benthic dynamics. Although adult wrasses use caves and other structures in rock and dead coral limestone substrates to a great extent and are not directly dependent on living corals, humphead wrasses are most numerous near abundant live coral. Moreover, in geological time even consolidated dead coral limestone substrates will decline as a result of weathering to form unconsolidated fines if the replenishment rates of stony corals decline. Concern over this factor, and coastal development (above) over a longer term was influential in the Team's conclusion that habitat loss could have moderate effects on extinction risk in the foreseeable future.

Overutilization

Estimates of overutilization have been hampered by a dearth of information regarding landings data and limited information on IUU fishing. Statements pertaining to harvest typically provide current landings estimates juxtaposed against some past level of harvest. Fisheries that land humphead wrasse appear to lack detailed temporal information pertaining to fishing effort, fishing power, harvest location, seasonal changes in landings, as well as the institution of management protocols. For example, IUCN (2008) notes a 10-fold decrease in market landings from Palau from the mid-1980s to mid-1990s, though fails to note that fishing with SCUBA-spear was banned in the early 1990s and may be directly linked to that stated decline. Although declines in landings were noted in some jurisdictions, in many locales information indicates no changes in landings or information on change is not available. This may be a result of humphead wrasse representing a minor component of most coral reef fisheries because of its natural rarity, or in some cases because of its already depleted status.

A significant amount of anecdotal evidence presented in Part I, in particular from within LRFFT participating countries, indicates that areas where at some past time period humphead wrasse were observed to have been present in what was believed to be natural densities are no longer found since the start of the LRFFT. Although these statements were not scientifically derived, many have been made by fisheries scientists or other well-informed individuals and are thus not readily dismissible.

Although overutilization appears to be a significant issue in some jurisdictions and locales (e.g., core-Coral Triangle area [Sadovy et al. 2003a; IUCN 2008]), amounting to moderate effects on extinction risk now and in the foreseeable future, it cannot be considered a significant or overriding impact on the species throughout its range in either time frame. In jurisdictions where SCUBA spearfishing has been banned (Fiji, Palau, the U.S. jurisdictions of American Samoa and CNMI) there is reasonable expectation that older and larger fish benefit from depth refugia. In the CNMI, SCUBA spearfishing is banned while it is not in Guam. As a result, there exists considerable disparity in the size frequency distributions of landed humphead wrasse between the jurisdictions (Figure 14), which falls in line with the conclusions of Lindfield et al. (2014) that the banning of scuba spearfishing results in depth refugia for many coral reef fish species.

Disease or Predation

The Team noted that the sparse information on disease and predation summarized in the review constituted a matter of low risk to the species throughout its range, either now or in the foreseeable future, with a certainty rating of medium for both time frames.

Inadequacy of Existing Regulatory Mechanisms

Across the wide Indo-Pacific range of the humphead wrasse, there exists a diversity of regulations, many of questionable effectiveness. In U.S. waters, most jurisdictions have regulations that afford partial to complete protection for the species, and these are, in general, reasonably enforced. These include federal annual catch limits based on what little is known of abundance, prohibitions on non-selective and destructive fishing gear (e.g., American Samoa and CNMI both ban SCUBA spearfishing, while Guam presently does not but is considering such a ban), an assortment of no-take marine protected areas (MPAs) around CNMI and Guam, and full prohibition on take around American Samoa and the Pacific Remote Island Areas.

Internationally, of the 48 countries where humphead wrasses occur, only about 18 have implemented regulations. This lack of consistent regulation may be due to abundance data being unknown, undocumented, or not attended to (e.g., Cambodia, Egypt, Kenya, Saudi Arabia, Somalia, Sudan, etc.), or the country does not participate in the legal international trade (e.g., Djibouti, Eritrea, Israel, Madagascar, Mayotte, Myanmar). Of countries that have regulations, most prohibit non-selective and destructive gear types, regulate minimum size limits, significantly reduce (or ban) export quotas, and/or have tightened enforcement loopholes—all within the last few years (Gillett 2010; Sadovy 2010; IUCN 2013; Sadovy unpublished). Only 12 countries are known to participate (or have participated) in the legal (reported) trade of the species (e.g., Federated States of Micronesia, Indonesia, Malaysia, Australia, Hong Kong, Japan, Netherlands, Papua New Guinea, Philippines, Singapore, Tonga, and Solomon Islands), while the number of countries participating in the illegal trade is unquantified. International regulation was the primary concern of the Team in finding that inadequate existing regulations have a moderate effect on extinction risk of the species.

Other international regulatory authorities include CITES, which lists the humphead under Appendix II with the following provisions: Legal trade is regulated, an export permit is required to show fish were legally acquired and harvesting is not detrimental to survival of the species, and the exporting country must have a functional management plan and associated monitoring. In addition, the importing country must closely monitor its imports. Sanctions or complete bans on exports provide strong incentive to comply. Additionally, IUCN lists the humphead wrasse as “endangered” while affording no regulatory protection; the hope is to promote awareness of the status of the species.

Regulations addressing overutilization include those that have substantially decreased (reported) legal trade of humphead wrasse. For example, from 2005-2011, ~82,000 live humphead wrasse were legally traded by 10 countries, whereas in 2012 (the most recent year of available data), only ~1,700 live humphead wrasse were legally traded by 5 countries. Indonesia decreased their export quota from 8,000 in 2005 to 1,800 in 2012 (IUCN 2013), and legally traded on 1,653 in 2012 (CITES 2014). Malaysia, which legally exported ~53,000 live humphead wrasse from 2007-2009 (CITES 2014), reached and has maintained a zero export quota since 2010. Hong Kong is now believed to be better controlling trade where it checks imports and re-exports, and coordinates verification of permits with Malaysia and Indonesia (Sadovy 2010). Countries that formerly exported for the LRFFT have also banned the export of the species (e.g., Australia, Federated States of Micronesia, New Caledonia, Niue, and Palau) (Gillett 2010). In other countries, national regulations have been tightened (e.g., Palau and Fiji), helping to close enforcement loopholes (Sadovy 2010). In Indonesia, recent field surveys at seven “baseline” sites found increased densities of humphead wrasse at four sites 4-5 years later. Most fish were juveniles, but the increase in numbers is encouraging and has occurred in areas where fishing pressure has evidently declined (IUCN 2013). At least a decade is believed to be a conservative time scale for these heavily exploited populations to begin recovery from fishing pressure following adequate protection (Colin 2010).

In the geographic center of the species range - the Coral Triangle Region - humphead wrasse is one of the most valuable species in the LRFFT, and has been for the past few decades. Countries within the Coral Triangle region are characterized by large and growing populations, particularly in coastal areas, where many consider fishing an occupation of last resort (non-land owners). Many nearshore fish stocks are heavily harvested, and recent declines in humphead wrasse landings probably reflect this fact more so than effectiveness of new regulations. In areas of this region where the LRFFT is not currently operating, any catch of this species would bring a good price at local markets (live or fresh). Local regulations to manage the trade that are contradictory to national regulations also exist in the area, and where illegal export is reportedly rampant (e.g., Philippines).

Misreporting continues to be an IUU fishing issue for the LRFFT in Southeast Asia, including mislabeled fish or fish hidden in exports (CITES 2010a; CITES 2010b; Sadovy et al. 2011). Undocumented shipments continue through Singapore. However, Hong Kong, the largest importer, has recently committed to controlling imports, re-exports, and possession within the territory, thus enabling a more secure system of trade (CITES 2010a). Additionally, most countries ban the use of cyanide, though it does continue in many areas due to lack of enforcement and corruption (Erdman and Pet-Soede 1997; Pet and Pet-Soede 1999; Yan 2011).

Numerous MPAs exist throughout the range of the humphead wrasse (see Figure 16). If adequately enforced, these sufficiently large MPAs might help reduce threats from the loss and modification of adult or juvenile habitat, destructive fishing practices, and overutilization. For example, in areas including Australia, Maldives, and Wake Atoll where some degree of protection for the species is afforded (e.g., take and possession prohibited, ban on exports, etc.) and adequately enforced, the risk of local “stock” depletion has been reduced and abundance of humphead wrasse in the area is stable or increasing (Sadovy et al. 2003 citing Sluka 2000; NMFS PIFSC CRED, unpublished data).

In summary, when considered across the entire range of the species, it is reasonably likely that the various existing regulatory measures will continue to benefit the humphead wrasse globally by appreciably reducing the threats to the species, presuming they are adequately enforced. The greatest threat - the LRFFT - appears to have decreased substantially, according to recent CITES trade data (CITES 2014). This reduction in legal trade may be due to either: 1) reduced or zero export quotas; or 2) reduced population sizes of humphead wrasse stocks within the three main exporting countries of Indonesia, Malaysia, and the Philippines. However, it is believed that much illegal (unreported) trade still continues, particularly in the several countries of the Coral Triangle region, and that declines in export volume may reflect more the increasing rarity of humphead wrasse due to overfishing, rather than regulatory compliance and wrasse population response. In spite of local pockets of questionable regulatory compliance, it is unlikely that inadequate existing regulatory mechanisms alone contribute more than moderately to the extinction risk for the humphead wrasse across its wide Indo-Pacific range either now, or in the foreseeable future.

Other Natural or Manmade Threats

The Status Review Report describes the life history characteristics, meager information on competition, and substantial concerns with regard to climate change and pollution considered by the ERA Team. The Team concluded that other natural or manmade threats would likely have some small effects on the extinction risk of the species now (over 0-25 years) and moderate effects over the foreseeable (26-50 years) future, the latter due to concerns of increased climate change and pollution-related impacts on the species, although with a decreased confidence in the certainty of these threats in the future.

11.3. Overall Risk Summary

Guided by the results and discussions from the demographic risk analysis and threats assessment, the ERA Team voted on the overall risk of extinction to the humphead wrasse based on the information the Team reviewed in its demographic risk analysis, as modified by the information reviewed in the threats assessment. The Team noted that although a demographic factor such as abundance had been judged moderately to highly likely to contribute significantly to risk of extinction, and that threats such as overutilization had been judged moderately likely to increase the species' extinction risk, that these judgments were about the likelihood of increments to extinction risk, not the level of overall extinction risk itself. The overall risk summary was the place that the Team made its judgment of the integrated effects of demography and threats on the level of extinction risk. The following table (Table 16) gives the results of the Team's likelihood point distribution. Likelihood points were tallied and the totals (n = 40) are presented for the overall level of extinction risk now and through the foreseeable future.

Table 16.--Overall risk summary for the humphead wrasse using 10 likelihood points per team member. Certainty ranking: Low (1), Medium (2), High (3). Certainty mean: Low = 1.0 or 1.25; Medium = 1.5, 1.75, or 2.0; High = 2.25 and up.

Overall level of extinction risk now (0-25 yrs)						
Team Member	**1 = No risk**	**2 = Low risk**	**3 = Moderate risk**	**4 = High risk**	**5 = Very high risk**	**Certainty**
A	7	2	1	0	0	M
B	5	4	1	0	0	M
C	8	2	0	0	0	H
D	5	5	0	0	0	M
MEAN						2.25
FREQUENCY	**25**	13	2	0	0	
RANGE	xxxxxxx	xxxxxxx	xxxxxxxxxxx			High
MODE	**No risk**					
MEDIAN	**No risk**					

Table 16 *continued*

Overall level of extinction risk through the foreseeable future (26-50 yrs)						
Team Member	**1 = No risk**	**2 = Low risk**	**3 = Moderate risk**	**4 = High risk**	**5 = Very high risk**	**Certainty**
A	3	5	2	0	0	L
B	4	4	2	0	0	L
C	6	3	1	0	0	M
D	2	6	2	0	0	L
MEAN						1.25
FREQUENCY	15	**18**	7	0	0	
RANGE	xxxxxxx	xxxxxxxx	xxxxxxxxxxxx			Low
MODE		**Low risk**				
MEDIAN		**Low risk**				

The ERA Team found that although demographic factors such as abundance and growth rate/productivity had a moderate likelihood of increasing the risk of extinction, and although threats such as overutilization or inadequate existing regulatory mechanisms were also moderately likely to increase that risk, the Team concluded that, though somewhat likely, the credible increments that each of these factors individually and collectively contribute to the overall extinction risk were too small to constitute an overall risk of extinction now to the humphead wrasse as a single unit throughout its range. For the level of extinction risk of the humphead wrasse now (0-25 years), the Team found no risk of extinction (mode and median = no risk), with only the tail of its distribution of likelihood points suggesting the possibility of low or moderate risk. The Team expressed this view with a high relative certainty (average of 2.25) with regard to the available information.

For the level of extinction risk of the humphead wrasse in the foreseeable future (26-50 years), the ERA Team predicted that the species would be at low overall risk of extinction (mode and median = low) with a substantial portion of its distribution of likelihood points indicating no risk, and a small proportion indicating moderate risk. The Team viewed the certainty of information for the foreseeable future as being low.

The likelihood point distribution did not extend into the range of high or very high risk of extinction now or in the foreseeable future. Despite its natural rarity and depressed abundance in certain areas, there was a high degree of consensus among the members of the Team that the risk of extinction is very low based primarily on the species' sustained widespread distribution throughout most of its known range, and its effective protection from exploitation at a variety of localities under both U.S. and foreign jurisdiction.

12.0. REFERENCES

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APPENDIX I–DPS ARGUMENTS FOR AND AGAINST DISCRETENESS AND SIGNIFICANCE

Arguments For and Against the Discreteness of the Core-CT DPS

Arguments for Discreteness as a Consequence of Physical Factors

While likely, it is not known if the humphead wrasse consists of more than one population throughout its range because genetic or other evidence is completely lacking, either for or against population structure. Separations caused by physical factors (barriers) such as distance, bathymetry, or current patterns might potentially separate some populations of humphead wrasse in the core-CT DPS from those outside. Conservatism with regard to population structure could be grounds to assume that physical factors might hypothetically isolate subpopulations within the core-CT DPS. Furthermore, the islands that comprise the proposed core-CT DPS equate to thousands of islands, many that largely enclose calm isolated seas or bays (e.g., Sulu Sea, Visayan Sea, Celebes Sea, Molucca Sea). Such bathymetry could greatly restrict larval exchange from surrounding areas, favoring sub-populations.

Arguments against Discreteness as a Consequence of Physical Factors

The overall range of the species extends from the western Indian Ocean to the eastern Pacific with no obvious gaps that might be due to physical limitations. Although some wider separations between islands or archipelagoes might hypothetically constrain planktonic larval dispersal, evidence of separation from genetic information is lacking and stock structure is unknown. The duration of the planktonic stage is unknown but if it were typical of many reef fish with planktonic larvae that settle to the benthos at 8-15 mm total length (mode 12 mm: Tupper 2007), it should be of sufficient duration (~25-45 days at representative larval fish growth rates of 0.2 - 0.4 mm day^{-1} (Victor 1991; Slamet and Hutapea 2005)) for recruitment to occur from islands and archipelagoes outside the core-CT DPS such as from Papua New Guinea, and the Solomon Islands in the east or Australia to the south. Although physical factors like deep bathymetry or prevailing currents might inhibit recruitment from some directions in some seasons, the location of the DPS in the center of the species' range provides potential sources of recruitment from other directions as well, including from India and Myanmar in the west, and Thailand and Viet Nam in the North. Spawning may occur in all months. Physical factors that might hypothetically separate some populations from others do not appear particularly relevant as the core-CT DPS boundaries touch adjacent coral coasts in Thailand, Papua New Guinea, and Timor-Leste. Thus, it seems very unlikely that the core-CT DPS is markedly separated by physical factors, as indicated by the Team's votes with scores ranging from 1 to 2 and a low mean score of 1.25. Certainty indicated by Team was also low (Table 17).

Arguments for Discreteness as a Consequence of Ecological and Behavioral Factors

The center or core of a species' geographic distribution is a generally recognized distinction that could be fundamental to its persistence. The humphead wrasse might be an important reef ecosystem component because of its trophic role as predator of both crown-of-thorns starfish

(COTS), an important coral predator, and Triton's trumpet gastropods, which is also an important predator of COTS. It seems likely that the ecological dynamics of these species differ between populations in the core-CT DPS where they overlap versus peripheral populations because the geographic distributions of the COTS and Triton's trumpets outside the CT DPS differ somewhat from that of humphead wrasse. The wrasse might be a key ecosystem interactor in the core-CT DPS, but not be where it, COTS, and trumpets do not overlap peripheral to the core-CT DPS.

The core-CT DPS also likely differs from peripheral regions within its range as a result of analogous differences in the spatial distributions of reef-associated biological resources (seagrasses, mangroves) that vary in whether they provide essential juvenile nursery habitat. For example, the humphead wrasse is found in the Commonwealth of the Northern Mariana Islands where mangroves are rare, but mangroves (and seagrasses) are also documented to provide nursery habitat only within the core-CT DPS and at a few other places outside the core-CT DPS like Tanzania.

Arguments against Discreteness as a Consequence of Ecological and Behavioral Factors

There are other countries in the species' range that are very near, if not completely central, to its range. There are some locations outside the core-CT DPS where humphead wrasse, COTS and Triton's trumpets co-occur, although maybe not so broadly. Similarly, mangroves and seagrasses commonly occur outside the bounds of the core-CT DPS where their role as nursery habitat is only partially known, and may be more common than documented. None of the aforementioned ecological and behavioral factors are convincingly discrete for the core-CT DPS, as indicated by the Team's scoring, which ranged from 1 to 2 with a medium mean score of 1.75. The Team's certainty on this factor was low (Table 17). These ecological and behavioral factors are more relevant to "Ecological Setting" in relation to the significance of the core-CT DPS than they are to distinctness.

Arguments for Discreteness as a Consequence of International Boundaries

This proposed core-CT DPS international boundary encompasses the geographic center of the species' range. The humphead wrasse is one of the most valuable species in the LRFFT, and has been for the past few decades (Sadovy et al. 2003a; Sadovy et al. 2003b; Gillett 2010). Numbers of humphead wrasse exported live have greatly diminished, most probably due to its increasing rarity, as fishing pressure including illegal, unregulated and unreported (IUU) fishing intensifies, while demand and value continue to increase. The majority of current activity by the LRFFT is from these three core-CT DPS nations. The LRFFT fishery operates by "fishing-out" a locality (e.g., bay or few island area), then moves on to a more productive area until it too is "fished-out." Connectivity and recruitment of pelagic larvae from areas not yet depleted, which exist mostly outside the core-CT DPS, may be a plausible explanation why local extirpation has not already occurred. Very large individuals (near maximum size) could be observed while diving in the Philippines several decades ago, while in recent years even juveniles are reportedly rare to find (Robert Schroeder, personal communication).

Large and growing human populations with coincident agricultural expansion and coastal development characterize the core-CT DPS countries. In coastal areas, where many consider fishing an occupation of last resort (non-land owners), many nearshore fish stocks have already been over-exploited, particularly those with more vulnerable life-history characteristics like humphead wrasse. In core-CT DPS areas where the international LRFFT is not currently exploiting humphead wrasse, any catch of this species would bring a good price at local markets (live or fresh). While possession of humphead wrasse is prohibited under Section 97 of Republic Act 8550 of the Philippine Fisheries Code of 1998 (including stiff fines), local regulations to manage the trade are contradictory and there is much illegal export (e.g., daily flights of LRFFT from Palawan to Hong Kong) despite it being an IUCN-listed "endangered species."

The major importing destinations of the trade are Hong Kong, mainland China, Taiwan, and Singapore (Sadovy et al. 2003a). The proximity of the core-CT DPS countries by air to these import destinations, and the proximity of the core-CT DPS countries to each other for export by another, combined with the limitations of governance create a high probability of IUU fishing for the LRFFT despite nominal institution of conservation regulations. This proximity makes the core-CT DPS countries more susceptible to this trade compared to other, adjacent coral triangle countries (i.e., Solomon Islands, Papua New Guinea) and other countries, as evidenced by past exports. The financial motivation for IUU is strong. Despite the extent of prime, core species habitat within the core-CT DPS, the abundance of the species is now lower there than in nearby countries (Australia and New Caledonia) or more distant countries (Fiji, Maldives, and Seychelles) that have had little or no participation in the LRFFT. Thus, the core-CT DPS is markedly distinct due to its higher risk of over-exploitation compared to the rest of the species' range, and it is the governance within the core-CT DPS rather than the species' biology, that is the source of this distinctness and risk.

The Team supported a finding of discreteness of the core-CT DPS as a consequence of international boundaries, with scores ranging from 2 to 3 and a high mean of 2.5. Certainty of the Team was also high for this factor.

Arguments against Discreteness as a Consequence of International Boundaries

During the past 20 years there have been enhancements in regulatory measures in the LRFFT countries of the core-CT DPS. Although IUU fishing for humphead wrasse still occurs (Bailey and Sumaila 2008; Sadovy de Mitcheson et al. 2010) and enforcement of existing laws and regulations continues to be problematic (Poh and Fanning 2012), enforcement protocols have been instituted to impose restrictions on landings, export has been banned in Australia, Fiji, Maldives, Palau, Philippines, and the Seychelles, and export size limits are in place in Indonesia and Papua New Guinea (Gillett 2010). Although there is certainty in the fact that illegal activities are occurring, there is also some certainty that improvements have occurred with respect to higher estimates of abundance or increased numbers of sightings of humphead wrasse at a few sites in Indonesia (Unsworth et al. 2007) and Malaysia (IUCN 2008). Moderate-to-high (relative to the core-CT DPS) densities of the species have sometimes been observed in the Coral Triangle countries not included in the proposed core-CT DPS (Papua New Guinea and the Solomon Islands; Sadovy et al. 2003), as well as in countries adjacent to the Coral Triangle such as Palau (Sadovy et al. 2003) and Australia (Sadovy et al. 2003; IUCN 2008). As humphead wrasse are still present in harvested regions in the proposed core-CT DPS, and nearby surrounding countries harbor the species, connectivity within the Coral Triangle and areas adjacent to it likely persists. However, as indicated, the Team was not convinced by these arguments against discreteness as a consequence of international boundaries.

Arguments For and Against the Significance of the Core-CT DPS

Arguments for Significance as a Consequence of Ecological Setting

The core-CT DPS is at the center or core of the humphead wrasse's geographic distribution and as such probably represents the original and most persistent habitat of the species. Should the species' range retract, the DPS is central to what could be that reduced range. The three countries of the DPS represent only about 5% of the countries and subordinate national entities that comprise the species' range, yet they contain about 50% of the mangroves and 30% of the coral reefs contained in its range. This assertion is based on the analysis of habitat by country in the bumphead parrotfish Status Review (Kobayashi et al. 2011: noting that the only locations not corresponding between the two species contain very minor proportions of the reef and mangrove habitat). Reef-associated habitat such as mangroves and seagrasses provide considerable humphead wrasse nursery habitat within the core-CT DPS as compared to areas outside the core-CT DPS (e.g., Tanzania).

The ecosystem role of humphead wrasse may be important because of its predation on COTS, an important coral predator, and its predation on Triton's trumpet gastropods, which also preys upon COTS. The core-CT DPS represents a relatively large region where all of these animals co-occur and are likely interdependent in their ecological roles, which may be governed by alternative dynamics where all three do not co-occur peripheral to the CT DPS.

The Team supported a finding of significance of the core-CT DPS as a consequence of ecological setting, with scores ranging from 2 to 3 and a high mean of 2.5. Certainty of the Team was medium for this factor.

Arguments against Significance as a Consequence of Ecological Setting

The humphead wrasse utilizes various habitat types during its life history. The species appears to select settlement substrate including branching coral with associated macroalgae (Tupper 2007), mangroves, and seagrasses, all of which vary considerably over the species' range. Therefore, restriction of a particular habitat type in one part of its range cannot be considered a limiting factor in recruitment. Sub-adults and adults tend to favor the structure of habitat rather than any specific type (e.g., live coral cover). The species has been observed breeding throughout its range, and evidence of recruitment has been noted in many areas such as Fiji (Jennings and Polunin 1996, 1997), Indonesia (Colin 2006), Philippines (IUCN 2008), Wake Atoll (Sadovy et al. 2003), American Samoa (Sabater et al. 2009), and the Commonwealth of the Northern Mariana Islands (CNMI DFW unpubl. data). The core-CT DPS may not be significantly important to the recovery or survival of the species as the connectivity between the DPS and other areas, although not well understood, is very unlikely to provide an essential source of recruits, especially to distant population segments in the western Indian Ocean as well as the western subtropical Pacific, where the species is less rare.

However, as indicated, the Team was not convinced by these arguments against the significance of the ecological setting of the core-CT DPS.

Arguments for Significance due to Loss of the DPS Creating a Significant Gap in the Species' Range

Local extirpation in the core-CT DPS could cut off the coastal continuity from Indian to Pacific Oceans that exists through Malaysia, Indonesia, and the likely continuity through the proximity of the Philippine Islands. The planktonic juvenile stage of the species up through a size of 8-15 mm total length (mode ~12 mm; Tupper 2007) only suggests that recruitment across open ocean from surrounding countries could occur. If recruitment as such does not occur, or if recruitment requires connectivity between adjacent islands, then the extirpation of the species within the core-CT DPS could eliminate the great majority of closely spaced islands connecting the species' range from the Indian to the Pacific. An easy pathway for recruitment from the Indian Ocean to the Pacific via coastal Australia is uncertain, because the species' range appears not to extend beyond the core-CT DPS to waters in the north of Australia (Figures 4 and 5) between its documented occurrence east of the York Peninsula (Allen and Erdmann 2012) and on offshore reefs of northwestern Australia (Sadovy et al. 2003a). Furthermore, the overexploitation and coastal development that might cause loss of the core-CT DPS could prevent successful repatriation.

Arguments against Significance due to Loss of the DPS Creating a Significant Gap in the Species' Range

The range of the species from the western Indian Ocean to the south central Pacific borders the core-CT DPS to the east and west such that the gap could be rapidly filled by recruitment were the species to become extinct within the core-CT DPS. The lack of genetic or other evidence either for or against any population structuring provides no guidance about whether or not recruitment would occur easily across the core-CT DPS boundaries, but the planktonic larval stage of the species up through a length of 8-15 mm suggests that recruitment across open ocean from surrounding countries could occur, and that regional extirpation of the species within the core-CT DPS would not result in a permanent gap in the species' distribution. Despite the pressures from the LRFFT and coastal development, the persistence of the core-CT DPS is probable evidence of continuing recruitment by pelagic larvae from outside the core-CT DPS such that a significant gap could not persist. The Team was not convinced that loss of the DPS would create a significant gap in the species' range, with scores ranging from 1 to 2, a low mean score of 1.25, and medium certainty.

Arguments for Significance because Focus on a Core-CT DPS Promotes Recovery

Establishment of the core-CT DPS will draw attention to the markedly distinct and higher risk of over-exploitation of humphead wrasse within the DPS compared to the rest of the species' range, and provide the US and international community the opportunity to better influence regulation and enforcement with regard to the LRFFT and IUU through diplomacy, capacity-building, and trade relations. Such designation could also promote international technical assistance (e.g., setting priorities for the current NOAA-USAID Partnership) to better understand the humphead wrasse (e.g., population structure, life history, ecology, behavior, stock assessment, local and international socio-economic aspects, maximum sustainable yield, etc.). Designation of this core-CT DPS could also provide mutual benefit to the efforts by IUCN to help recover this "IUCN endangered species." Designation could help promote compliance in the core-CT DPS, where enforcement of regulations has, so far, been largely ineffective. Although there are many locations outside the core-CT DPS that could be the focus for recovery, cumulative habitat area of the oceanic islands (small, steep drop-offs) most likely to receive adequate protection is small relative to core-CT DPS.

The Team mean vote was just high enough to find that this factor was significant. Votes ranged from 2 to 3 with a high mean of 2.25 and medium certainty.

Arguments against Significance because Focus on a Core-CT DPS Does not Promote Recovery

Although populations of humphead wrasse in the centrally located core-CT DPS *might* produce planktonic stages that disperse to reefs beyond the core-CT DPS regions (i.e., act as "source" populations that seed propagules peripherally), it is also perhaps just as likely that the core-CT DPS populations are "sinks." Propagules produced elsewhere but recruited within the core-CT DPS are then subject to higher subsequent mortality resulting from more extreme overfishing and other anthropogenic environmental impacts such as sedimentation and coastal development. The latter are expected to result in a greater loss of nursery habitat in these developing countries with increasing human population densities. Better environmental conditions and lower levels of fishing mortality at isolated oceanic islands in the central and western Pacific might provide (now and in the future) better spatial refuges for the species and thus a better focus for recovery efforts.

If it is determined that the species is less at risk outside of the core-CT DPS, there is some likelihood of less attention and recovery efforts being made within the US jurisdictions and elsewhere. Conservation is needed throughout the range of this vulnerable species of concern. Without establishing the same level of concern for survival of the species outside the core-CT DPS, there is some chance that US effort to support improved governance in the core-CT DPS could be observed as unfair. The main impact of focus on the core-CT DPS would be to improve its local and regional recovery. The recovery of the rest of the species is not greatly influenced by the core-CT DPS, and the core-CT DPS is not nominated as a "significant portion of the range" (SPOIR) for the species. Nevertheless, these arguments were not convincing, as indicated by the Team's high mean score of 2.25 and medium certainty.

Table 17.--Distinct Population Segment Analysis of the "Core-Coral Triangle" area – Philippines, Malaysia, and Indonesia.

Scoring: 1= low **markedness** or low **importance**, 2 = medium, 3 = high. Certainty ranking: L= low (1), M = medium (2), H = high (3)						
Discreteness = **markedly** separate from other populations as a consequence of:						
	Physical factors	Certainty Ranking	Ecological and Behavioral factors	Certainty Ranking	International Boundaries	Certainty Ranking
Range	1 to 2	L to M	1 to 2	L	2 to 3	M to H
Mean	**1.25**	**Low**	**1.75**	**Low**	**2.5**	**High**
Significance = **importance** of the population segment to the overall welfare of the species.						
	Ecological Setting	Certainty Ranking	Significant Gap	Certainty Ranking	Promotes Recovery	Certainty Ranking
Range	2 to 3	M	1 to 2	L to H	2 to 3	L to M
Mean	**2.5**	**Medium**	**1.25**	**Medium**	**2.25**	**Medium**

APPENDIX II–PHOTOS OF HUMPHEAD WRASSE

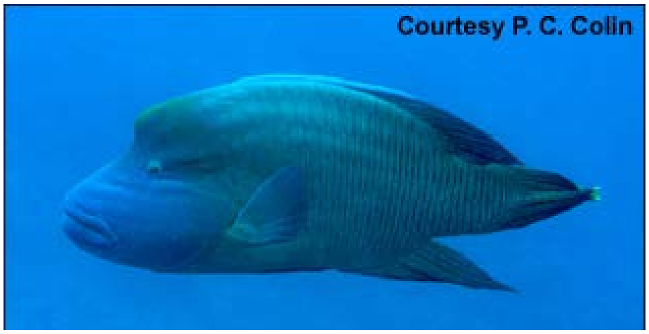
In Malaysian Borneo's Kota Kinabalu City, a single one-kg fish can retail for USD $115 (photo by Gregg Yan; Yan 2011).

Juvenile humphead wrasse for sale in Penang, Northwestern Peninsular Malaysia (photo by Gregg Yan; Yan 2011).

Photo: M. McCoy, in: Gillett 2010

Photo: P.L. Colin

Male about to spawn with a small female Photo: P.L. Colin



Male with courtship posture with pointed caudal and anal fins. Photo: P.C. Colin

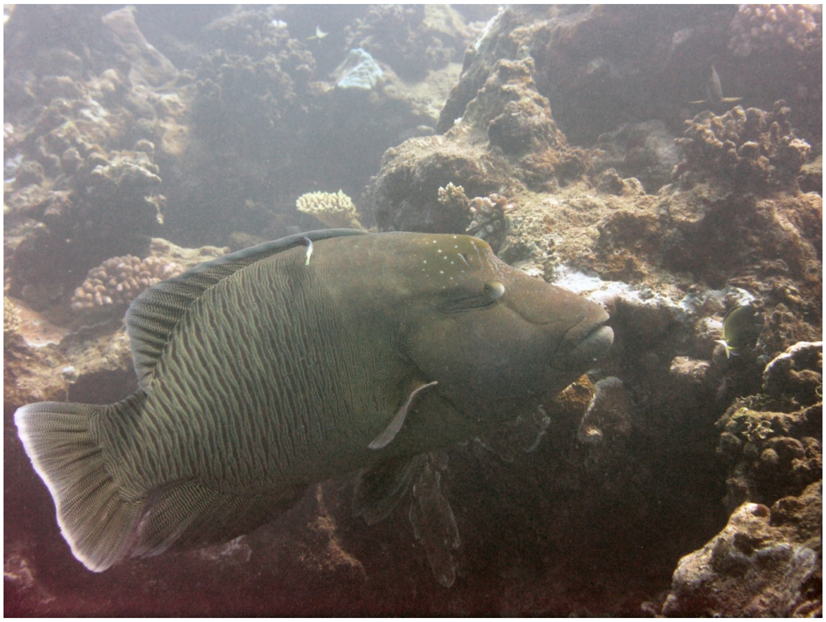


Photo: Robert Schroeder, Kwajalein Atoll 2009

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