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Protected Resources

Recovery Status Review

for the Main Hawaiian Islands Insular False Killer Whale Distinct Population Segment

August 2020

(*Version 1.0*)

Cover photo by Robin Baird, Cascadia Research Collective.

Contents

EXECUTIVE SUMMARY

We, NOAA Fisheries, listed the main Hawaiian Islands insular false killer whale (MHI IFKW; *Pseudorca crassidens*) as an endangered distinct population segment (DPS) under the Endangered Species Act (ESA) on November 28, 2012 (77 FR 70915). We completed a comprehensive status review in 2010 (Oleson et al. 2010) and a supplemental information report in 2012 (Oleson et al. 2012). Those two documents informed the listing decision. This document, the Recovery Status Review, contains a comprehensive collection of information for the MHI IFKW, with updated information collected since 2012. New text, information, and citations are in a blue text color to more easily allow readers to identify information since the 2012 listing.

We intend for this Recovery Status Review to be a comprehensive living document that we update with significant new information as it becomes available. For example, because NOAA Fisheries publishes stock assessment reports (SARs) annually for marine mammal stocks, any updated information for the MHI IFKW (e.g., population size, trend) in the most recent SAR will be updated in this document.

A Recovery Status Review does not result in a decision. Rather, it provides the best scientific and commercial data available to inform management and recovery actions for ESA listed species. It serves as the “Background” section of a recovery plan and information base for ESA section 7 consultations, grant allocations, permitting, section 10 conservation plans, and 5-year reviews.

False killer whales are long-lived social odontocetes that are found throughout all tropical and temperate pelagic waters. Within the Hawaiian Archipelago, three populations (stocks) of false killer whales are currently recognized for management under the Marine Mammal Protection Act (MMPA): a pelagic population, a main Hawaiian Islands insular population, and a Northwestern Hawaiian Islands population (Carretta et al. 2018; Figure 2–2). The MHI IFKW is the only false killer whale DPS listed under the ESA.

The MHI IFKW is both discrete from and significant to the global taxon, thus meeting the criteria for classification as a DPS under the ESA based on genetic, behavioral, ecological, and cultural factors. It is a unique island-associated population with a range that entirely surrounds the main Hawaiian Islands. The most recent abundance estimate was 167 (SE=23; 95% CI=128–218) animals within the surveyed area in 2015 (Bradford et al. 2018) and is based on encounter data from dedicated and opportunistic surveys for MHI IFKWs from 2000 to 2015 to generate annual mark-recapture estimates of abundance over the survey period. Annual estimates over the 16-year survey period ranged from 144 to 187 animals within the surveyed area in that year and are similar to multi-year aggregated estimates previously reported (Oleson et al. 2010). Several lines of evidence since 1989 suggest that the abundance of MHI IFKWs has declined over the last few decades. However, because of inter-annual variability in survey effort, it is unknown whether the abundance of MHI IFKWs has continued to decline, has recently stabilized, or has recently increased (Bradford et al. 2018).

There is significant social structure (i.e., relationships between individuals) within MHI IFKWs. Social network analyses once divided MHI IFKWs into three broad social clusters or groups based on connections (Newman 2006, Martien et al. 2011, Baird et al. 2012); however, increased information from field studies indicates more complexity in these social connections and a fourth and fifth social cluster have recently been identified (Mahaffy et al. 2017, Robin Baird, Cascadia Research Collective, pers. comm. March 2019) (Figure 2–6).

Feeding primarily on fish and squid, MHI IFKWs are considered top predators. Their primary prey includes many of the same species targeted by Hawai‘i-based commercial and recreational non-longline fisheries (i.e., fisheries using hooks and a mainline length of less than 1 nautical mile in various configurations and techniques including troll, handline, kaka line, and shortline), especially tuna, billfish, wahoo, and mahi mahi. The overlap in space and target species between the MHI IFKW and fisheries in Hawai‘i results in several threats.

The original 2010 status review (Oleson et al. 2010) and final listing rule identified 29 historical, current, and future threats to MHI IFKWs. For recovery planning purposes, and as a logical outgrowth of the 2016 recovery planning workshop for the species (NOAA Fisheries 2017a), we have updated and restructured the threats for clarity and to better prioritize them relative to each other in terms of informing post-listing recovery activities. We used the best available information, some of which has become available since the final listing rule, to consolidate the threats down to 19 current and future threats (a 20th threat, live capture for aquaria, is considered an historical threat) and ranked them in terms of highest to lowest relative concern (Table 3–1). The top three threats of highest relative concern are incidental take in non-longline commercial and recreational fisheries, inadequate regulatory mechanisms (management and reporting) of non-longline commercial and recreational fisheries, and small population size. The next level of relative concern includes competition with non-longline commercial and recreational fisheries and environmental contaminants and naturally occurring biotoxins, followed by climate change, anthropogenic noise, and cumulative/synergistic effects. Additional threats in the least relative concern categories include competition with commercial longline fisheries, habitat effects (e.g., marine debris, oil spills), other types of interactions (e.g., marine structures such as aquaculture facilities and wind/solar farms, whale/dolphin watching and other ecotours, commercial longline fisheries, intentional harm, and vessel strikes), and other natural factors like predation (e.g., killer whales and tiger sharks) and competition with marine species (e.g., marlin, sharks).

Finally, we summarize conservation measures for MHI IFKWs. Current conservation measures in place for MHI IFKWs can be grouped into four categories: (1) protections afforded through the ESA, including the State of Hawai‘i’s ESA section 6 Cooperative Agreement; section 7 consultations; section 9 take prohibitions; and section 10 permits and habitat conservation plans; (2) protections afforded through the MMPA, including take prohibitions, the authorization of incidental take under the MMPA, and the False Killer Whale Take Reduction Plan; (3) active research programs to fill data gaps; and lastly (4) outreach and education, including marine wildlife viewing guidelines.

LIST OF REVISIONS

[In the future, this section will summarize what revisions were made and when, and will be color coded so they are easy to find. Example:

Revision 1 (Date) – Revision to abundance estimate and Nmin estimate (pg x) [purple color]

Revision 2 (Date) – xxx (pg x)

Revision 3 (Date) – xxx (pg x) …]

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

LIST OF TERMS, ABBREVIATIONS, AND ACRONYMS

CEC	Chemicals of Emerging Concern
CI	Confidence Interval
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	Centimeters
CML	Commercial Marine License
CPUE	Catch-Per-Unit-Effort
dB	Decibel
DDT	Dichlorodiphenyltrichloroethane
Delisting	Removal from the list of Endangered and Threatened Wildlife and Plants
DLNR	Department of Land and Natural Resources
DNA	Deoxyribonucleic Acid
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
FKWTRP	False Killer Whale Take Reduction Plan
FKWTRT	False Killer Whale Take Reduction Team
ft	Feet
HTA	Hawaiʻi Tourism Authority
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	Kilohertz
kg	Kilogram
km^2	Square Kilometers
lbs	Pounds
LLEZ	Longline Exclusion Zone
LOQ	Limits of Quantization
MHI IFKW	Main Hawaiian Islands Insular False Killer Whale
mi	Miles
mi^2	Square Miles
mm	Millimeters
MMPA	Marine Mammal Protection Act
M&SI	Mortality and Serious Injury
mt	Metric Ton
nm	Nautical Mile
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWHI	Northwestern Hawaiian Islands
NWFSC	Northwest Fisheries Science Center
PBDE	Polybrominated Diphenyl Ether
PBR	Potential Biological Removal
PCB	Polychlorinated Biphenyl
PIRO	Pacific Islands Regional Office

POP	Persistent Organic Pollutant
SAR	Stock Assessment Report
SE	Standard Error
TRP	Take Reduction Plan
US	United States

1 INTRODUCTION

1.1 History of the Main Hawaiian Islands Insular False Killer Whale ESA Listing and Recovery Planning

On October 1, 2009, we, NOAA Fisheries, received a petition from the Natural Resources Defense Council requesting that we list the MHI IFKW as endangered under the ESA. On January 5, 2010, we determined that the petitioned action presented substantial scientific and commercial information indicating that the petitioned action may be warranted, and we requested information to assist with a comprehensive status review of the species to determine if the MHI IFKW warranted listing under the ESA (75 FR 316). We subsequently formed a biological review team to review the status of the species and produce a comprehensive status review report (Oleson et al. 2010).

After reviewing the best scientific and commercial information available, including the status review report (Oleson et al. 2010), we determined that the MHI IFKW was a DPS that qualifies as a species under the ESA. Moreover, after evaluating threats faced by the MHI IFKW, and considering efforts being made to protect them, we determined that the MHI IFKW is declining and is in danger of extinction throughout its range. On November 17, 2010, we proposed to list the MHI IFKW as an endangered DPS under the ESA (75 FR 70169), and solicited comments for a total of 90 days from all interested parties. A public hearing on the proposed rule was held on January 20, 2011, in Honolulu, Hawaiʻi.

Following the publication of the proposed listing rule in November 2010 (75 FR 70169), a previously unrecognized Northwestern Hawaiian Islands (NWHI) population of false killer whales was identified. Updated satellite tagging information and other new research papers on the MHI IFKW also became available. Because the new NWHI population was identified as a separate population for management purposes (Carretta et al. 2013) and since this new information could have been relevant to the final determination of whether the MHI IFKW qualified as a DPS for listing under the ESA, we reconvened the biological review team. On September 18, 2012, we published a Notice of Availability in the Federal Register (77 FR 57554) announcing this new information and reopened public comment for a 15-day period pertaining to the new information. On October 11, 2012, the biological review team published their report, titled "Reevaluation of the DPS Designation for MHI IFKWs" (Oleson et al. 2012).

On November 28, 2012, after considering the best scientific and commercial data available, we finalized the proposed rule and listed the MHI IFKW as an endangered DPS under the ESA (77 FR 70915). This final rule became effective on December 28, 2012.

In September 2016, we released a recovery outline. The recovery outline served as an interim guidance document to direct recovery efforts, including recovery planning, for the MHI IFKW until a full recovery plan was developed and approved.

We designated critical habitat for the MHI IFKW on July 24, 2018 (83 FR 35062). The total area of designation includes 45,504 km^2 (17,569 mi^2) of marine habitat in waters from 45 meters to 3,200 meters in depth surrounding the main Hawaiian Islands (from Niʻihau to Hawaiʻi). The area does not include most bays, harbors, or coastal in-water structures and excludes 14 areas (15 total sites) from the designation due to economic and national security impacts.

In October 2016, we held a 4-day workshop to gather information and perspectives on how to recover MHI IFKWs to the point where protections under the ESA were no longer needed. Over 40 experts from a range of relevant disciplines were invited to participate in the workshop. We included expertise in the following topic areas: biology, life history, foraging ecology, oceanography, acoustics, contaminants, commercial and recreational fishing, federal and state fisheries management, and recovery planning. The workshop was open to the public and public comment was invited at the end of each day. Feedback during the workshop as well as the workshop summary (NOAA Fisheries 2017a) were used to update and restructure the threats to MHI IFKWs for clarity and to better prioritize the threats relative to each other in terms of informing post-listing recovery activities.

1.2 Distinct Population Segment Overview

Under the ESA, the term "species" includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." A DPS must be "discrete" from other populations and "significant" to the taxon (species or subspecies) to which it belongs. We determined that the MHI IFKW was both discrete from other populations and significant to the taxon, thus it was evaluated and listed as a DPS. Details of the discreteness and significance analyses can be found in the status review report (section 3.0; Oleson et al. 2010) and final listing rule (77 FR 70915).

The terms "species" and "DPS" are used interchangeably in ESA documents because in the ESA context, "species" actually refers to the listed entity. Because there is some biological and ecological information that is based on other false killer whale populations but applies to MHI IFKWs, we wish to distinguish between the two terms for clarity. We want to be clear on what information is derived from research on the DPS itself, versus information derived from other false killer whale populations. As such, for the purposes of this document, the term "species" refers to the taxonomic species (i.e., false killer whales as a whole) and the term "DPS" refers to the MHI IFKW, the ESA-listed entity. Additionally, and as discussed further in section 2.4.1, MHI IFKWs are described the same as defined under the MMPA (although the MMPA refers to the population as a "stock").

1.3 Approach to the Recovery Status Review

This document is a Recovery Status Review for the MHI IFKW. It contains information on MHI IFKWs' biology and status to inform ESA actions, and can be periodically updated with new information. This Recovery Status Review is the most comprehensive source for the MHI IFKWs' biological and status information needed for many ESA decisions (e.g., section 7 consultations, grant allocations, permitting, section 10 conservation plans, 5-year reviews, and recovery planning).

In this Recovery Status Review, we compiled pertinent information from the original 2010 biological status review report (Oleson et al. 2010) and the 2012 DPS reevaluation report (Oleson et al. 2012) that were completed as part of the listing process for the MHI IFKW, additional biological and ecological information from the final listing rule (77 FR 70915), information found in the most recent SAR (the final 2019 SAR (85 FR 46589; August 3, 2020) is the most recent, but no changes were made to the MHI IFKW, so we refer to the final 2017 SAR (Carretta et al. 2018) when changes were last made to the population)), relevant publications since the MHI IFKW was listed in late 2012, as well as information from the Recovery Outline (NOAA Fisheries 2016). This Recovery Status Review serves as the most comprehensive source of information on the MHI IFKW for future ESA decisions, but not for past decisions.

The intent of a Recovery Status Review is to provide a succinct yet comprehensive and regularly updated characterization of a species' status. While the information in this document is not a full compilation of unabridged text from the other aforementioned sources, it is also more than a mere summary. However, original sources (e.g., the status review report, DPS reevaluation, final listing rule, SAR, etc.) may contain a more exhaustive description or explanation and, like any reference cited, should be referenced back for more contextual information, where appropriate or where noted. For example, the status review report (Oleson et al. 2010) contains more information on the global distribution of false killer whales (section 2.1.3), the oceanographic environment of the Pacific Ocean and Hawaiian Archipelago (section 2.2), the marine species in the central North Pacific Ocean and Hawaiian Archipelago (section 2.2.5), an introduction to cetacean genetics (section 2.3), and genetic case studies of proxy cetaceans (section 2.3.1.1), etc. Because this document focuses specifically on MHI IFKWs, we have chosen to narrow the focus of information in many sections, but note where additional information on the global species can be found.

Additionally, because we intend for this Recovery Status Review to be a comprehensive document that incorporates newer information, we have chosen to differentiate newer information via text color. That said, in many parts of this document there is very little, if any, new information on topics such as identifying characteristics, taxonomy, many aspects of life history, as well as information on some threats to the species. Therefore, original and/or summarized information (primarily from the 2010 status review (Oleson et al. 2010), unless otherwise noted) will be in black text. More recent data is available from an increase in sample sizes (e.g., from biopsies, photo-identifications (photo-IDs), satellite tagging), a re-analysis of range, and recent strandings and associated examinations, etc. Newer information and citations are in a blue text color to allow readers to more easily identify new information.

Finally, a Recovery Status Review does not result in a decision. Rather, it provides the best scientific and commercial data available to inform management and recovery actions for ESA listed species. It serves as the "Background" section of a recovery plan and information base for section 7 consultations, grants, permitting, section 10 conservation plans, and 5-year reviews.

2 SPECIES INFORMATION

2.1 Identifying Characteristics

2.1.1 Size and Shape

The false killer whale, *Pseudorca crassidens* (Owen 1846), is a slender, large delphinid. Maximum reported sizes are 610 cm for males (Leatherwood and Reeves 1983) and 506 cm for females (Perrin and Reilly 1984). Length at birth has been reported to range from 160 to 190 cm, and length at sexual maturity is 320 to 427 cm in females and 367 to 457 cm in males (Stacey et al. 1994, Odell and McClune 1999, Ferreira et al. 2014). Both sexes grow 40 to 50% in body length during their first year of life, but males subsequently grow faster. Growth is reported to cease between 20 and 30 years of age, and there is evidence of geographic variation in asymptotic body length (i.e., difference in body size (from birth to sexual maturity) depending on geographic location (Ferreira et al. 2014)). Both sexes of false killer whales are 10–20% longer off the coast of Japan (i.e., asymptotic length is 46 cm (females) and 56 cm (males) longer than off the coast of South Africa (Ferreira et al. 2014)). It is not clear where along the size range continuum the MHI IFKW may fall; only a few stranded animals have been measured and they have been relatively small (Baird 2016). West et al. (2016) reports two female false killer whales ages 20 and 22 measuring 405 and 421 cm, respectively, and one male false killer whale age 24 measuring 445 cm. Large adult males may weigh up to 2200 kg (~4,850 lb) (Reidenberg and Laitman 2008).

Coloration of the entire body is black or dark gray, although lighter areas may occur ventrally between the flippers or on the sides of the head. A prominent, falcate dorsal fin is located at about the midpoint of the back, and the tip can be pointed or rounded. The head lacks a distinct beak, and the melon (a mass of adipose tissue found in the forehead of all toothed whales that is a key organ involved in communication and echolocation) tapers gradually from the area of the blowhole to a rounded tip. In males, the melon extends slightly further forward than in females. False killer whale pectoral fins have a unique shape among cetaceans, with a distinct central hump creating an S-shaped leading edge (Figure 2–1).

Figure 2–1. Biological illustration of false killer whale. © NOAA Fisheries 2016

2.1.2 Internal Anatomy – Skeleton

The skull of the false killer whale is characterized by a short, broad rostrum, with a length that is at least 1.5 times the width. Mean condylobasal (skull) length was reported to be about 59 cm based on 99 individuals from the North Atlantic Ocean, as summarized in Odell and McClune (1999). False killer whales generally have 7 to 10 conical teeth in each side of the upper jaw and 8 to 10 teeth in each side of the lower jaw. Wear patterns on teeth in older animals indicate that false killer whales can make backwards and lateral jaw movements to break up large prey (Ross 1984). The postcranial skeleton most commonly has 48 to 50 vertebrae, but as few as 47 and as many as 52 vertebrae have been reported (Stacey et al. 1994). There are 9 to 12 pairs of ribs, 4 of which attach directly to the sternum. The phalanges or finger bones of the pectoral fins show a wide degree of variation in structure. Facial structure, skull symmetry, and skew are similar to those reported for other delphinids, with the greatest similarities to bottlenose dolphins (*Tursiops* spp.) (Mead 1975).

2.1.3 Internal Anatomy – Organs

Most information on internal organs of false killer whales has been obtained from specimens from drive fisheries off the coast of Japan and mass strandings in the North Atlantic and in South Africa (Kasuya 1986, Odell and McClune 1999, Ferreira 2008). Blood parameters from stranded individuals and captive animals in oceanaria or research facilities are similar to those measured for other small cetaceans (Stacey et al. 1994, Odell and McClune 1999). The musculature and soft tissues of the head are involved in sound production, but there are differences in the amount of connective tissue anterior to the melon in males and females (Mead 1975). The diploid chromosome count for false killer whales ($2n$=44) is typical for cetaceans. At sexual maturity, male testes weigh 1.0 to 1.7 kg, with maximum testes mass reported as 8.2 kg (Odell et al. 1980).

2.2 Taxonomy

As discussed in the 2010 status review (Oleson et al. 2010), the false killer whale is considered a single species with no proposed subspecies. Only one study has been conducted on the taxonomy of false killer whales (Kitchener et al. 1990) that showed differences among some populations (e.g., body growth and sexual dimorphism), though no taxonomic revisions were proposed. Currently, based on application of ESA policy, the MHI IFKW is a DPS of the global species (Oleson et al. 2010).

No global comparison to examine taxonomic questions has been conducted using genetic data for false killer whales because of the limitations of sample distribution (but see Martien et al. 2014). For a species like the false killer whale, with its global distribution restricted to tropical and temperate waters and with strong social structure (i.e., relationships between individuals), the state of their taxonomy below the species level remains uncertain. A 2004 workshop that was convened to consider cetacean taxonomy rated false killer whales as having a medium level of taxonomic uncertainty (Reeves et al. 2004).

2.3 Life History

2.3.1 Global Distribution and Density

False killer whales are long-lived social odontocetes (toothed whales) that occur in all tropical and warm-temperate oceans, generally in deep offshore waters but also in some shallower semi-enclosed seas and gulfs (e.g., Sea of Japan, Yellow Sea, Persian Gulf (Leatherwood et al. 1989) and Timor Sea and Arafura Sea (Palmer et al. 2017)), near oceanic islands (e.g., Hawaiʻi, Johnston Atoll, Galapagos, Guadeloupe, Martinique) (Leatherwood et al. 1989), and regularly in shallow, continental shelf waters off northeastern New Zealand (Zaeschmar et al. 2014). More specific information on the global distribution of false killer whales can be found in the status review report (section 2.1.3; Oleson et al. 2010).

False killer whales are uncommon relative to other tropical cetaceans and other tropical odontocetes. Densities of false killer whale populations vary widely and their density decreases in sub-tropical locations. In the central and eastern Pacific Ocean, densities range from 0.02 to 0.38 animals per 100 km^2 (Wade and Gerrodette 1993, Mobley et al. 2000, Ferguson and Barlow 2003), with the lowest densities reported for waters north of about 15° N off Baja California, Mexico, and within the U.S. exclusive economic zone (EEZ) of Hawaiʻi. Highest densities are reported in waters surrounding Palmyra Atoll. Unlike other cetacean species that can be found along both continental margins and in offshore pelagic waters (e.g., bottlenose dolphins), false killer whale densities do not appear to increase closer to coastlines.

Although false killer whales are found globally, the genetic, morphometric, and life history differences indicate there are distinct regional populations (Kitchener et al. 1990, Chivers et al. 2007, Ferreira 2008; Martien et al. 2014). Within the Hawaiian Archipelago, three false killer whale populations (stocks) are currently recognized for management under the MMPA: a pelagic population, a main Hawaiian Islands insular population, and a NWHI population (Carretta et al. 2018; Figure 2–2). Only one population is listed under the ESA.

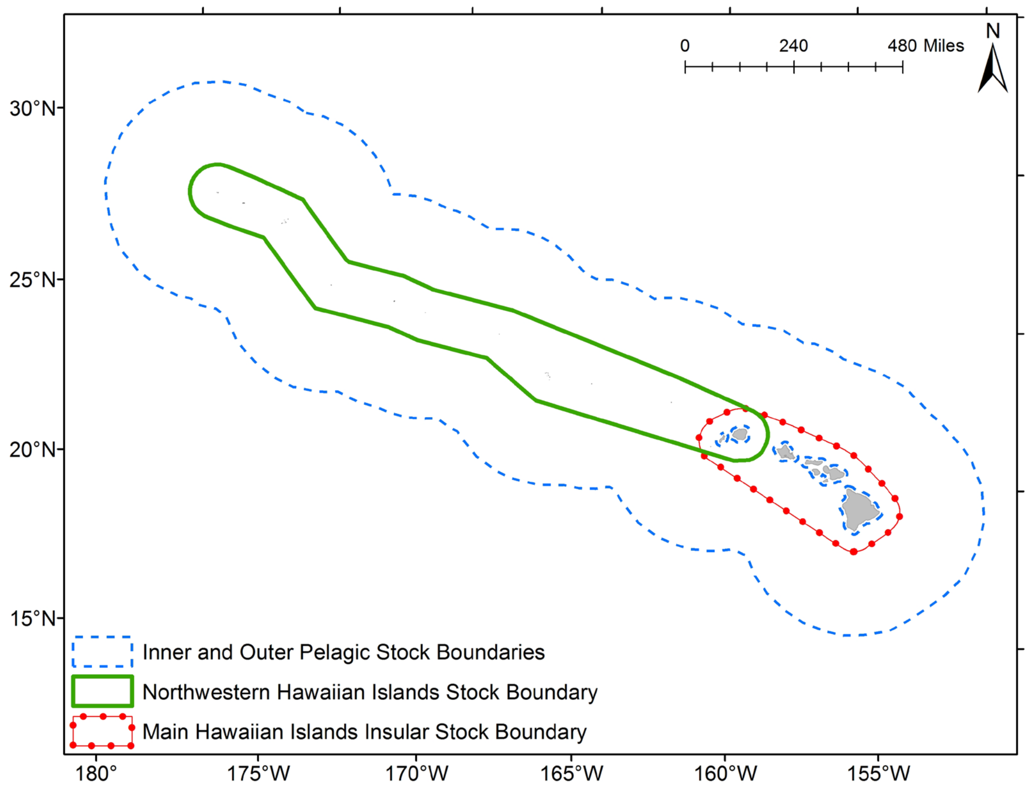

Figure 2–2. False killer whale population boundaries in Hawaiʻi.

2.3.2 Population Dynamics

Much of what we know of the life history of false killer whales as a taxonomic species is derived from necropsies of dead animals. Specimens have originated from drive fisheries in Japan and a stranding off South Africa. The Japan specimens included 96 females (including 57 mature females) from 6 schools of healthy animals driven ashore at Iki Island to reduce fishery interactions in 1979 and 1980 (Kasuya and Marsh 1984, Kasuya 1985, Kasuya 1986). The South African specimens included 65 false killer whales that stranded off the Atlantic coast in 1981 (data available from 41 females, including 32 mature) (Purves and Pilleri 1978, Kasuya 1985, Ferreira 2008, Ferreira et al. 2014). Since social groupings of false killer whales appear to stay together during mass strandings (Porter 1977) and drive fisheries (T.K. pers. comm., cited in Photopoulou et al. 2017), it is assumed that the stranding and drive fisheries included the entire social group (Photopoulou et al. 2017).

Ferreira (2008) compared the large sample sizes from the Japanese drive fisheries and the South African stranding event and found the following general trends: females were about 84% of the length of males and tended to dominate the sex ratio in these populations at 0.63; males between the ages of about 8 and 18 were not found in the groups sampled, which may indicate some dispersal of subadult males until they reach full sexual maturity; and both males and females stopped growing between 25 and 30 years of age. The oldest estimated age (based on growth layers in teeth) was 63 years for females and 58 for males. Estimated age at sexual maturity is about 8 to 11 years for females, while males may mature 8 to 10 years later (Kasuya 1986).

Dispersal patterns of male false killer whales from their natal schools (i.e., group into which an individual is born) are poorly understood (Ferreira et al. 2014). The limited number of males of various size classes in the samples from Japan and South Africa suggests that some maturing males might leave their natal schools at least temporarily, but that others may remain with or return to their natal groups (Ferreira et al. 2014). A stranding of 181 false killer whales in Chile reported an absence of large juveniles and sub-adults of both sexes (Alonso et al. 1999, Ferreira et al. 2014). A 2013 stranding of 22 false killer whales on the east coast of the Falkland Islands also had only mature adults. Of the 20 that were sexed, 11 were male and 9 were female (Crofts et al. 2019). While sperm whales (*Physeter macrocephalus*) are known to form bachelor groupings and a group of bachelor long-finned pilot whales (*Globicephala melas*) has been observed once (Desportes et al. 1993), this type of social grouping has only been observed in false killer whales off northeastern New Zealand. There, mature males are regularly observed to form close groups, with visible segregation from the larger groups but still clearly considered part of the larger groups (Jochen Zaeschmar, pers. comm. 2019). Ferriera et al. (2014) reasoned that false killer whale males may rove singly or in very small groups, as is evidenced by false killer whales off northeastern New Zealand (Jochen Zaeschmar, pers. comm. 2019). However, there is no evidence of lone males or all-male groups of MHI IFKWs (Robin Baird, Cascadia Research Collective, pers. comm. 2019).

More recent research from Martien et al. (2019) investigated mating patterns of MHI IFKWs using both genetic and photo-ID data. The authors identified 32 parent-offspring pairs, revealing strong natal social group fidelity for both sexes. Their research indicates that between 36 and 64% of matings involved individuals from the same social group or cluster. The authors surmise that because the population declined between the 1980s and early 2000s, the intra-group matings may be the result of reduced opportunities for inter-group matings since the decline. Prior to the decline, social groups may have been sufficiently large that selective pressure to develop inbreeding avoidance mechanisms was low, or MHI IFKWs may have evolved alternate inbreeding avoidance mechanisms such as kin recognition (Martien et al. 2019).

As for female false killer whales, findings from Chivers et al. (2010), in which females within a single group had different genetic haplotypes, indicate that even among females, groups are composed of more than near-relatives. Ferreira (2008) suggested their mating system may be polygynous (i.e., one male lives and mates with multiple females) based on the large testes size of males, but actual understanding of the mating system remains poor.

Females ovulate spontaneously one or more times per year (Stacey et al. 1994), and calving in tropical waters may occur year-round. Ovulation rates decrease with age, and females between 45 and 55 years are post-reproductive (Kasuya 1986, Ferreira 2008, Photopoulou et al. 2017). The reported proportion of females pregnant each year ranges wildly, from estimates of 14 to 21% (Perrin and Reilly 1984 (citing data from Purves and Pilleri 1978 and Kasuya and Izumisawa 1981, respectively)), to 14.93% (10/67) for the Japanese schools combined, and 2.7% (1/37) for the South African sample (Kasuya 1986, Ferreira 2008). The only reported birth interval, 6.9 years between calves, is from Japan (Kasuya 1986).

However, annual pregnancy rates were reported as 11.4% for Japan and 2.19% for South Africa (Ferreira 2008). Oleson et al. (2010) calculated a rough inter-birth interval by taking the inverse of the annual pregnancy rate, which would yield an 8.8-year interval and a 45-year interval for Japan and South Africa, respectively (note that a calculation error in Oleson et al. (2010) reported this as 4.5-year interval, and it was noted that in the sample for South Africa, only 1 of 37 adult females was pregnant, suggesting that this group may be insufficient to estimate pregnancy rates). A shorter average inter-birth interval would be calculated from an annual pregnancy rate were it to exclude post-reproductive females.

The estimated reproductive rates of false killer whales in both Japan and South Africa are low compared to those of other delphinids and especially compared to the two species with the most similar life history—killer whales and short-finned pilot whales (*Globicephala macrorhynchus*)—which have a 5 and 8.8-year interbirth interval, respectively (Taylor et al. 2007). The inter-birth interval for the MHI IFKW is unknown; however, the relatively low productivity in the central tropical Pacific Ocean may mean that MHI IFKWs have a longer inter-birth interval than false killer whales found in areas with higher productivity.

Ferreira (2008) provided comparisons of the life history parameters inferred from the Japanese drive fishery samples and the South African stranding sample. As previously discussed, results indicated that whales in Japan attained a larger asymptotic body size (10 to 20% larger) and grew faster. Also, aspects of the whales in Japan indicated a higher reproductive rate: the ratio of reproductive to post-reproductive females was higher and the pregnancy rate was higher than in South Africa. Possible reasons given by Ferreira (2008) for the apparently higher reproductive rate in Japan are 1) Japanese whales are exhibiting a density-dependent response to population reduction as a result of exploitation, 2) colder waters near Japan are more productive, or 3) they are eating yellowtail tuna (*Seriola quinqueradiata*) (Kasuya 1985) as opposed to the South African whales that eat primarily cephalopods (Best 2007).

Female false killer whales enter menopause and become reproductively senescent with age. Ferreira (2008) estimated senescence (based on lack of macroscopic follicles observed in the ovaries) at approximately 45 years old. Using the same data set as Ferreira (2008) (animals from the South Africa stranding and the Japanese drive fisheries), further histological examination of the ovaries was undertaken by Photopoulou et al. (2017) to confirm macroscopic observations and reproductive status. The authors found that ovulation had ceased in 50% of whales over 45 years, and all whales over 55 years old had ovaries classified as post-reproductive. The authors also found morphological and statistical evidence of changes in the activity of the ovaries in relation to age (Photopoulou et al. 2017). Reproductive senescence is quite rare in cetaceans, but has also been documented in killer whales and other social odontocetes (e.g., short-finned pilot whales and sperm whales). The two primary reasons given for reproductive senescence are increasing survival of offspring as a result of care given by multiple females of multiple generations (grandmothering), and transmission of learning across generations allowing survival in lean periods by remembering alternative feeding areas or strategies (McAuliffe and Whitehead 2005, Ferreira 2008).

Wade and Reeves (2010) argue that odontocetes are more vulnerable to exploitation than mysticetes (baleen whales) and have delayed recovery when numbers are reduced. The authors argued this was because of the combination of their life history, which results in exceptionally low maximum population growth rates and the potential for social disruption. Particularly if older females are lost, it may take decades to rebuild the knowledge required to achieve maximum population growth rates. The authors give numerous examples from both cetaceans (beluga whales (*Delphinapterus leucas*), killer whales, and sperm whales are particularly pertinent) and elephants, which are similarly long-lived social animals with reproductive senescence.

2.3.3 Feeding Ecology and Food Requirements

2.3.3.1 Feeding Ecology

False killer whales are top predators, eating primarily fish (Peacock et al. 1936, Scheffer and Slipp 1948, Bullis and Moore 1956, Tsutsumi et al. 1961, Schevill 1965, Brown et al. 1966, Shallenberger 1981, Silas et al. 1984, Kasuya 1985, Evans and Awbrey 1986, Baird et al. 1989, Baird 2009) and squid (Deraniyagala 1945, Bullis and Moore 1956, Ross 1984, Baird et al. 1989, Cagnolaro et al. 2002, Hernandez-Garcia 2002). They also have been reported occasionally attacking other marine mammals (Perryman and Foster 1980, Palacios and Mate 1996), but some of these reports are not substantiated with photos or have been questioned (Hoyt 1983, Rinaldi et al. 2007, Baird 2018a). They are also known to attack sharks (unknown shark species in drone footage in Sydney, Australia (Kataoka 2016); and depredation of blue sharks caught on Spanish longlines (Ramos-Cartella and Mejuto 2008)). These impressions are based on relatively limited data from various parts of the species' extensive range. The data include both stomach contents from stranded animals and observations of feeding by free-ranging whales, and the sources may have differing biases. There may also be a seasonal component in prey preference; in Japan, prey shifted seasonally from mackerel to squid (Tsutsumi et al. 1961).

False killer whales feed both during the day and at night (Evans and Awbrey 1986, Baird et al. 2008a). The large, dispersed groups in which false killer whales typically occur (Baird et al. 2008a, Baird et al. 2010), and their patchily distributed prey suggest that this species forages cooperatively. Although they hunt in dispersed subgroups, they converge when prey is captured. Further evidence for the social nature of false killer whale foraging is the observation of prey sharing among individuals in the group (Connor and Norris 1982, Baird et al. 2008a).

2.3.3.2 Energetic Needs

Several evaluations of energy needs have been conducted for captive false killer whales. An initial estimate of 4.7% of body weight per day was made by Sergeant (1969). However, it was noted by Van Dyke and Ridgway (1977) that a 454-kg adult consumed 40 kg/day (8.8% of body weight) and a 353 kg/juvenile consumed 50 kg/day (14.2% of body weight). Kastelein et al. (2000) reported estimates of daily consumption rates of 2.9% to 6.1% of body weight, and Baird (2009) reported values of 3.0% to 4.2%. Information on energetic needs specific to MHI IFKWs is discussed in section 2.4.7 below.

2.3.4 Diving Behavior

A study by Minamikawa et al. (2013) of a tagged false killer whale foraging in pelagic waters of the western North Pacific Ocean provided 70 h of dive data. First, the authors calculated the estimated aerobic dive limit of the species, or maximum time an animal can remain submerged without utilizing anaerobic metabolism, at 18.5 minutes. The maximum dive duration of the 3-m tagged *Pseudorca* was 14.6 minutes, i.e., 79% of its calculated aerobic dive limit. While this result is in contrast to the behavior of beaked whales that dive more slowly and for longer periods of time (Tyack et al. 2006, Minamikawa et al. 2007), it likely can be explained by an increased oxygen consumption rate related to false killer whales' ability to swim fast (Minamikawa et al. 2013). Second, data revealed that the tagged individual often performed downward sprints from depths of 300 to 500 m, presumably revealing that prey were detected at 300 to 500 m to which they rushed. These high-speed sprints may have resulted in the short dive duration (Minamikawa et al. 2013). Third, data also revealed that the durations of deep dives with a sprint were shorter than those of deep dives without a sprint. If the false killer whale adopts the same foraging tactics as short-finned pilot whales, which search for prey during intervals of slower descent and then chase and capture prey with sprints, then the 300 to 500 m layer would be the preferred search layer above the expected prey depth. The authors conclude that this high-risk tactic from the viewpoint of energy budget is suitable when an animal can obtain enough energy from the prey, such as neritic or mesopelagic squid and fish, the primary food of false killer whales (Alonso et al. 1999, Odell and McClune 1999, Baird et al. 2008).

Minamikawa et al. (2013) also revealed that deep dives were rarely performed at night, and both descent rate and ascent rate were significantly lower at night than during the daytime for both shallow dives and deep dives. Additionally, the number of dives >10 m per hour was greater at night than in daytime in this study, although statistical tests could not be applied to these results. Thus, the authors were unable to conclude whether the false killer whales actively foraged at shallow depths or decreased activity at night. Lastly, Minamikawa et al. (2013) strongly suggest that because of the propulsive efficiency of a false killer whale, their superior swimming ability possibly enables them to chase faster prey and feed at greater depths during the day even though the deep scattering layer is deeper than at night.

More recent data from tagged MHI IFKWs indicates that these animals are capable of diving deeper than earlier reported depths. Depth-transmitting LIMPET satellite tags were deployed in 2010 collecting 1,550 hours or 64.6 days of behavior data from four individuals from two MHI IFKW social clusters (three from Cluster 3, one from Cluster 1; social clusters discussed in section 2.4.4), with similar sample sizes during the day (35.7 days) and at night (28.9 days). Looking at information from all four animals, average maximum dive depths were similar during the day and night (912 m and 1,019 m, respectively). The data show that these individuals are diving >50 m about twice as often during the day (0.71 dives/hour) than at night (0.32 dives/hour). The maximum depth documented was 1,272 m and maximum dive duration was 18.65 minutes (Robin Baird, Cascadia Research Collective, pers. comm. 2017). In summary, data (from four individuals tagged in 2010 during the months of October and December) indicate that a majority of foraging activity happens during the day, but that some nighttime activity also includes foraging.

2.3.5 Social Behavior

2.3.5.1 Pod Structure

There is quite a bit of variance in estimates of group size of false killer whales. At least some of the variability stems from estimation methods and time spent making the group size estimate. False killer whales are most commonly observed in groups of about 10 to 20 animals (Wade and Gerrodette 1993, Baird 2009, Baird et al. 2010). In the Hawaiian Archipelago, most group sizes estimated from boats or planes averaged from 20 to 30 individuals, and group size estimates increased with encounter duration up to 2 hours (Baird et al. 2008). False killer whales can also be found in widespread aggregations of small groups, totaling hundreds of individuals (Wade and Gerrodette 1993, Baird 2009, Reeves et al. 2009). These large aggregations can be spread over tens of kilometers yet appear to have coordinated movement directions (Baird et al. 2008a). It is possible that the groups seen on typical surveys are only part of a larger group spread over many miles (e.g., Baird et al. 2010) that are in acoustic contact with one another.

In addition to variability in group size estimation, group size may also be influenced by water temperature and the associated productivity (e.g., Gygax 2002). For example, groups of false killer whales in New Zealand waters are considerably larger (mean=47) than those reported from Hawaiian waters but are consistent with those observed in Japanese and South African waters. Photo-ID from New Zealand waters confirms that these large groups are stable and not aggregations (e.g., Zaeschmar et al. 2013, Zaeschmar 2014). False killer whales in New Zealand waters appear to primarily target large schools or aggregations of fish that are unevenly distributed over large areas. Large group size is therefore beneficial to foraging success and large groups are likely to be stable in other temperate regions where the species occurs.

Large aggregations of false killer whales are also documented by worldwide mass stranding events. For example, mass strandings of large groups of false killer whales (ranging from 50 to 835 individuals, which is 4 to 5 times higher than live groups (Ferreira 2008)) have been documented in New Zealand, Australia, South Africa, the eastern and western North Atlantic, and Argentina, where the largest stranding on record occurred in 1946 when 835 whales beached themselves (Ross 1984). In the United States, Florida has had a number of mass strandings of false killer whales (ranging from 2 to 175 individuals) (e.g., Odell et al. 1980, Waring et al. 2013). More recently, in January 2017, 96 false killer whales stranded and perished along the remote coast of Southwest Florida in Everglades National Park. The group included adults, juveniles, and calves (Miami Herald 2017; NOAA Fisheries Office of Protected Resources, unpublished data 2017). Groups of 2 to 201 false killer whale individuals (mean=99) have also been driven ashore in Japanese drive-fisheries (Kasuya 1986). Analysis of age, sex, and maturity status from these mass mortality events indicates that these large groups include about equal numbers of males and females of various sizes (Odell and McClune 1999).

The social organization of smaller groups has been studied extensively in false killer whales near the main Hawaiian Islands (Baird et al. 2008a) as well as in New Zealand (Zaeschmar et al. 2014), where individuals in both locations are known to form strong long-term bonds (see section 2.4.4). False killer whales are also known to associate with other cetacean species, especially bottlenose dolphins (Leatherwood et al. 1988, Zaeschmar et al. 2013, Baird 2016). Interestingly, records also show false killer whales harassing other cetaceans, including sperm whales and bottlenose dolphins (Palacios and Mate 1996, Acevedo-Gutierrez et al. 1997).

2.3.5.2 Breeding

Little is known about the breeding behavior of false killer whales in the wild, but some information is available from captive false killer whales (Brown et al. 1966, Funasaka et al. 2018). Funasaka et al. (2018) examined three captive females from the Ocean Expo Park in Japan over 10 years. The estimated mean estrous cycle length was 40.5 ± 0.7 days (n=12); the seasonality of ovulation, estimated from the elevation of progesterone levels, varied among individuals or years; and ovulation did not occur every year. Seasonal peaks of progesterone levels (in spring and summer) in captive individuals suggest a seasonal aspect to reproduction (Atkinson et al. 1999, Kasuya 1986). Ferreira et al. (2014) found the evidence weak but it appears that there is some seasonal aspect to reproduction, at least in some populations.

The gestation period for the captive Japanese false killer whales lasted for 14 months until parturition. This comports with gestation estimates of 15.1 months for Japanese false killer whales and 14.4 months for South African false killer whales (Ferreira 2008). Females with calves lactate for 18 to 24 months (Perrin and Reilly 1984). In captive settings, false killer whales have mated with other delphinids, including short-finned pilot whales and bottlenose dolphins. Captive bottlenose dolphins have produced viable hybrid offspring with false killer whales (Odell and McClune 1999).

2.3.6 Acoustic Sensory System

False killer whales have a highly evolved acoustic sensory system, which they rely on for navigation, foraging, and communicating. The musculature and soft tissues of the false killer whale head (melon) are involved in producing and receiving sound, of which there are two general types: (1) whistles (tonal frequency-modulated signals), and (2) clicks (broadband pulsed signals) (Herman and Tavolga 1980). Whistles are primarily used for communication, whereas echolocation clicks are used for detection, localization, and target classification in spatial orientation and foraging (e.g., Herman and Tavolga 1980, Au 1993).

The vocalization range for false killer whales is as low as 4 kHz and as high as 130 kHz, with variable dominant frequencies depending on the age and gender of the individual (Croll et al. 1999 citing Kamminga and van Velden 1987, and Thomas and Turl 1990, respectively). Source levels from free-ranging whales were reported by Madsen et al. (2004) from 201–225 dB (re: 1µPa-m), while a study of a captive false killer whale reported a maximum peak-to-peak level (re: 1 µPa @ 1 m) of sounds of 228 dB (Thomas and Turl 1990). Studies from captive animals indicate that this dynamic ability to produce different sounds aids false killer whales in a variety of tasks, including detecting objects at a distance, discriminating between different objects, and intercepting prey (Thomas and Turl 1990, Brill et al. 1992, Madsen et al. 2004, Wisniewska et al. 2014).

A false killer whale's hearing is conservatively estimated between approximately 150 Hz and 160 kHz (Southall et al. 2007, NMFS 2018), classifying them in the mid-frequency hearing category.

In a captive environment, Thomas et al. (1988) conducted an underwater audiogram on a young (4-year old) false killer whale and reported the most sensitive range of hearing from 16 to 64 kHz, but noted that the whale had good sensitivity (i.e., within -40 dB) from 8 to 105 kHz (Thomas et al. 1988 as cited in Thomas and Turl 1990). Yuen et al. (2005) conducted an audiogram on a 30-year old captive female false killer whale and reported best sensitivity between 16 and 24 kHz and peak sensitivity at 20 kHz for behavioral data. Notably, the researchers hypothesized that this whale may have experienced hearing loss associated with age or presbycusis, because earlier studies indicated exceptional hearing capabilities for this animal. Kloepper et al. (2010) reported a decrease in echolocation performance for this individual following the high-frequency hearing loss and suggested that hearing at ultrasonic frequencies may have evolved in response to pressures for fine-scale echolocation discrimination. Au et al. (1997) tested hearing sensitivity of this species to a low-frequency 75 Hz phase modulated, 195 dB (re: 1µPa-m) source level acoustic signal and reported thresholds of 140.7±1.7 dB for a 75-Hz pure tone signal and 139.0±1.1 dB for the phase modulated signal.

2.4 Ecology of Main Hawaiian Islands Insular False Killer Whale DPS

Sections 2.1 through 2.3 of this document provide information that summarizes what we know about false killer whales as a species. This section, 2.4, provides information that is more specific to the biology and ecology of the MHI IFKW DPS.

2.4.1 DPS Description

A number of genetic, morphometric, and life history differences indicate there are distinct regional populations of false killer whales (Kitchener et al. 1990, Chivers et al. 2007, Ferreira 2008, Martien et al. 2014a, 2014b, NMFS 2016). MHI IFKWs were identified as a DPS under the ESA in 2010 (Oleson et al. 2010), as well as in the final listing rule under the ESA (November 28, 2012; 77 FR 70915). Since 2010, a new population of false killer whales (not listed) was recognized in the NWHI (Martien et al. 2011, Oleson et al. 2012, Baird et al. 2013, Carretta et al. 2013). More extensive sampling of false killer whales from the main Hawaiian Islands and pelagic waters has also occurred that strengthened the evidence for differentiation of the MHI IFKW population from all other false killer whale strata including the NWHI population (Martien et al. 2014a, 2014b). Genetics as it relates to the social network of MHI IFKWs is discussed in section 2.4.4.

2.4.2 Range

The range of the MHI IFKW extends from west of Niʻihau to east of Hawaiʻi Island (Figure 2–3). The range was originally set to include waters to 140 km from shore based on the maximum distance documented offshore with an additional buffer to reflect uncertainty based on the small sample size and seasonal and social group biases in the telemetry data. Since then, new telemetry data has provided a stronger basis to assess the range and suggests a smaller range than what was defined in 2010. The larger sample size has continued to show less offshore movement on the windward sides of the islands (maximum distance from shore = 51.4 km (Baird et al. 2010, Bradford et al. 2015)) than on the leeward sides of the islands (maximum distance from shore = 114.9 km), and thus the range has been re-evaluated taking into account these windward/leeward differences (Bradford et al. 2015).

Based on the larger samples size, and considering uncertainty in the data, NOAA Fisheries revised the boundary of MHI IFKW under the MMPA to be a minimum convex polygon bounded around a 72-km radius of the main Hawaiian Islands, resulting in a boundary shape that reflects greater offshore use in the leeward portion of the main Hawaiian Islands (Bradford et al. 2015) (see Figure 2–4). At the same time, NOAA Fisheries also revised the boundaries for other false killer whale populations in Hawaiʻi. This revised range of the MHI IFKW overlaps with the revised range of other nearby populations (Bradford et al. 2015, Carretta et al. 2018).

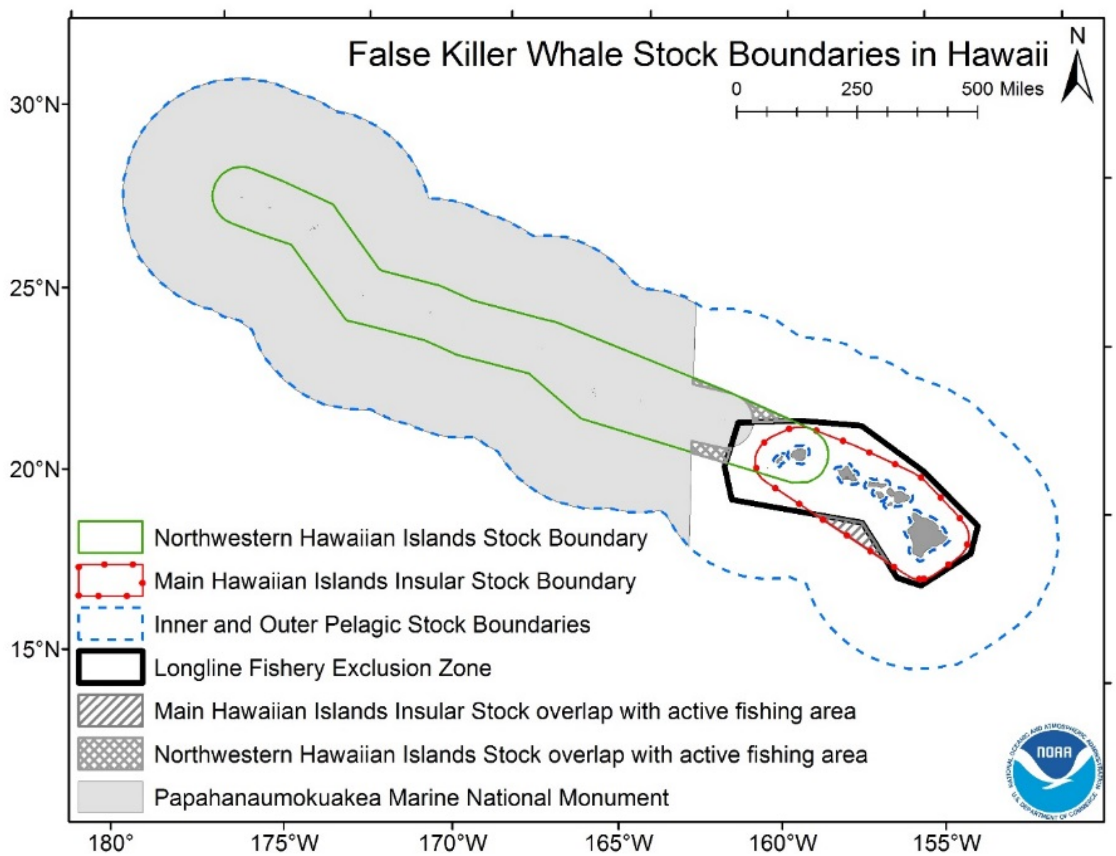

Figure 2–3. Revised false killer whale population boundaries and areas of population overlap. (Source: NOAA Fisheries unpublished 2016 (modified from Bradford et al. (2015) to reflect the change in the Papahānaumokuākea Marine National Monument boundary in 2016)

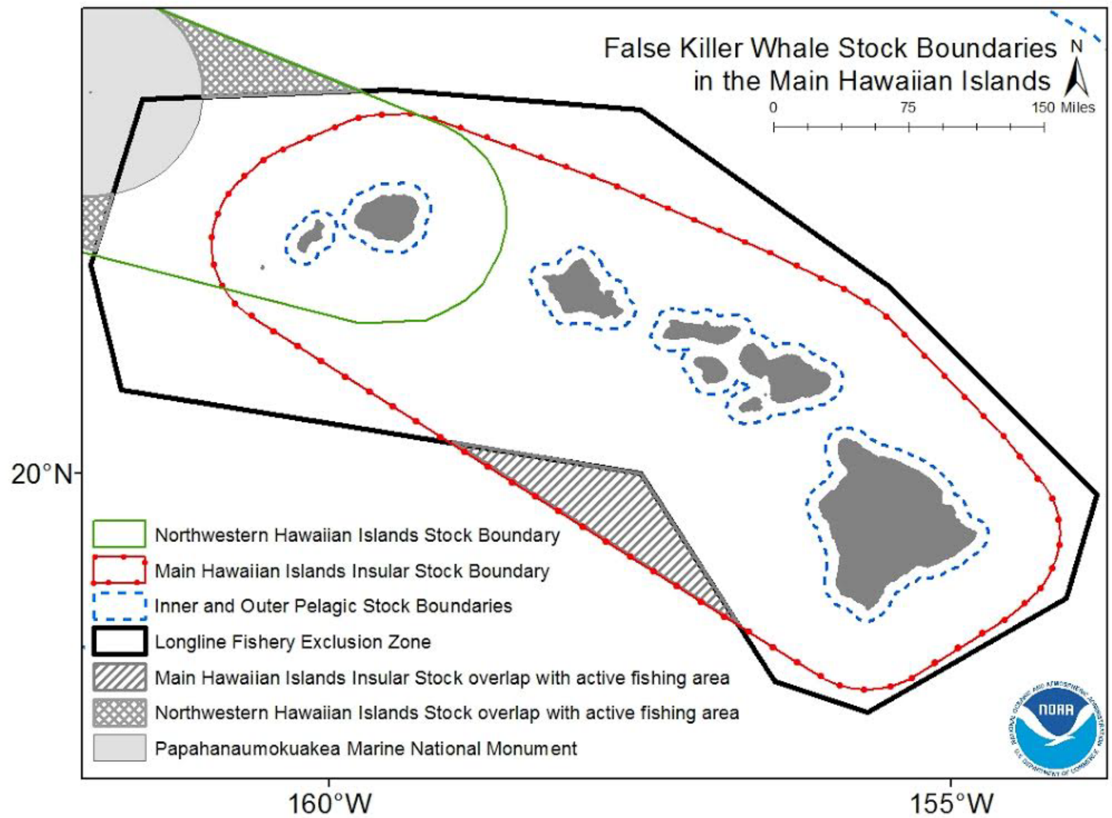

Figure 2–4. Close-up of revised MHI IFKW boundary. (Note the outer pelagic population boundary can be seen in the blue dashed line in the top right corner.) (Source: NOAA Fisheries unpublished 2016 (modified from Bradford et al. 2015))

2.4.3 Abundance, Trends, and Effective Population Size

Per the 2017 final SAR (Carretta et al. 2018), Bradford et al. (2018) used encounter data from dedicated and opportunistic surveys for MHI IFKWs from 2000 to 2015 to generate annual mark-recapture estimates of abundance over the survey period. Due to spatiotemporal biases imposed by sampling constraints, annual estimates reflect the abundance of MHI IFKWs within the surveyed area in that year, and therefore should not be considered indicative of total population size every year. The abundance estimate for 2015 was 167 (SE=23; 95% CI=128–218) animals within the surveyed area. Annual estimates over the 16-year survey period ranged from 144 to 187 animals and are similar to multi-year aggregated estimates previously reported (e.g., Oleson et al. 2010). Note that because the study area was partially sampled each year, the annual abundance estimates apply only to the portion of the population using the sampled area and may underestimate true population abundance (Bradford et al. 2018). Although total estimated abundance is low, this is considered a high population density relative to other sub-tropical regions and suggests the main Hawaiian Islands are a unique habitat capable of supporting a larger population density than nearby oligotrophic waters (Oleson et al. 2010).

The minimum population estimate for the MHI IFKW is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al. 1995) of the 2015 abundance estimate (from Bradford et al. 2018), or 149 false killer whales (Carretta et al. 2018).

As discussed in the status review report (Oleson et al. 2010), historical population size of the MHI IFKW is unknown. A plausible historical abundance with known caveats was estimated at 769 animals. This was based on the density of false killer whales around Palmyra Atoll (0.38 animals per 100 km^2), where the highest density of this species has been reported (Barlow and Rankin 2007), and extrapolated out to the 202,000 km^2 area of the population boundary (Oleson et al. 2010). Since the range of the MHI IFKW has recently been revised (172,268 km^2; Bradford et al. 2015), and is smaller than previously thought, using methods from Oleson et al. (2010) results in a revised plausible historical abundance estimate of 655 animals.

Aerial survey sightings from 1989 to 2003 suggest that the MHI IFKW population has declined over the last few decades. A survey conducted on the leeward sides of the main Hawaiian Islands in June and July 1989 report 14 sightings of false killer whales, including three large groups (group sizes 470, 460, and 380 individuals) very close to shore off Hawaiʻi Island (Reeves et al. 2009). These large group sightings were all in an area known to be a high-density area for MHI IFKWs based on satellite tagging data (Baird et al. 2012). The largest group seen in 1989 is almost three times larger than the current best estimate of the population size. From 1993 to 2003, five systematic aerial surveys indicated declining false killer whale encounter rates, with eight groups seen in 1993, nine in 1995, one in 1998, and no false killer whales (individuals or groups) seen in 2000 and 2003 (Mobley et al. 2000, Mobley 2004). The large group sizes observed in 1989, together with the declining encounter rates from 1993 to 2003, suggest that MHI IFKWs have declined substantially until at least the early 2000s (Reeves et al. 2009). Baird (2009) also reviewed the trends in sighting rates of false killer whales from these aerial surveys and concluded that sighting rates during these surveys showed a statistically significant decline that could not be attributed to any weather or methodological changes. Additionally, Silva et al. (2013) analyzed the number of sightings per hour of effort off Maui Nui across three methods of data collection (e.g., opportunistic, directed, and systematic boat-based surveys). Results suggest that the encounter rate of false killer whales in leeward Maui County waters in 1995 was over five times greater than in 2011, supporting the hypothesis of a population decline.

Based on our current understanding of population structure and geographical overlap between the MHI IFKW and other nearby unlisted populations, it seems unlikely that the large group sizes of false killer whales observed in 1989 were exclusively comprised of MHI IFKWs (Baird et al. 2012). For many years, scientists assumed false killer whales observed within 40 km of shore were MHI IFKWs. More recently, the pelagic population has been observed closer to shore (as close as 5.6 km offshore; Bradford et al. 2020). However, sightings of pelagic individuals within 40 km of shore are extremely rare; in 73 false killer whale sightings over an 18-year period within 40 km of shore, only one was a pelagic group, seen 22.8 km from shore (Robin Baird, Cascadia Research Collective, pers. comm., May 2019). Despite uncertainty about the historical population size, there is high confidence in the current estimated population size of 167 MHI IFKWs within the surveyed area in 2015. And as mentioned above, because the study area was partially sampled each year, the annual abundance estimates apply only to the portion of the population using the sampled area and may underestimate true population abundance (Bradford et al. 2018).

Because of inter-annual variability in survey effort, it is currently unknown whether MHI IFKWs have continued to decline, have recently stabilized, or have recently increased. The annual abundance estimates available in Bradford et al. (2018) are not appropriate for evaluating population trends, as the study area varied by year, and each annual estimate represents only the animals present in the study area within that year (Carretta et al. 2018). At a minimum, we will reexamine the extinction risk of the MHI IFKW once every five years to address new information available on this endangered species.

As discussed in Oleson et al. (2010), microsatellite genetic data was used to estimate the effective population size of MHI IFKWs as 45.8 individuals (95% CI=32.4 to 69.4 individuals). Due to an increased sample size of biopsies, Martien et al. (2019) have now estimated the effective population size as 57.6 individuals (95% CI=47.2–71.8). The effective population size reflects the size of an idealized population that would experience genetic drift in the same way as the actual (census) population (Chivers et al. 2010). Because there are multiple lines of evidence that MHI IFKWs declined until at least the early 2000s (Baird 2009, Reeves et al. 2009, Oleson et al. 2010, Silva et al. 2013), and because the animals are long-lived, many of the individuals still alive today likely were born prior to the decline. Domestic (i.e., non-wild) animals have been shown to start displaying lethal or semi-lethal genetic traits when effective population size reaches about 50 individuals (Franklin 1980). Although negative genetic effects cannot be predicted for a group of wild individuals that are probably naturally uncommon with a strong social structure that limits genetic diversity, the low effective population size of 57.6 individuals (Martien et al. 2019) accordingly remains a concern as it is still quite near the estimate of when individuals start displaying lethal or semi-lethal genetic traits.

2.4.4 Social Network and Group Dynamics

Photo-ID and social network analyses indicate that MHI IFKWs have a tight social network (Baird et al. 2010, 2012, Robin Baird, Cascadia Research Collective, unpublished data 2019) (Figure 2–5), and assessment of satellite telemetry collected from 38 tagged MHI IFKWs shows movements restricted to the main Hawaiian Islands (Baird et al. 2010, 2012, Robin Baird, Cascadia Research Collective, pers. comm. 2019).

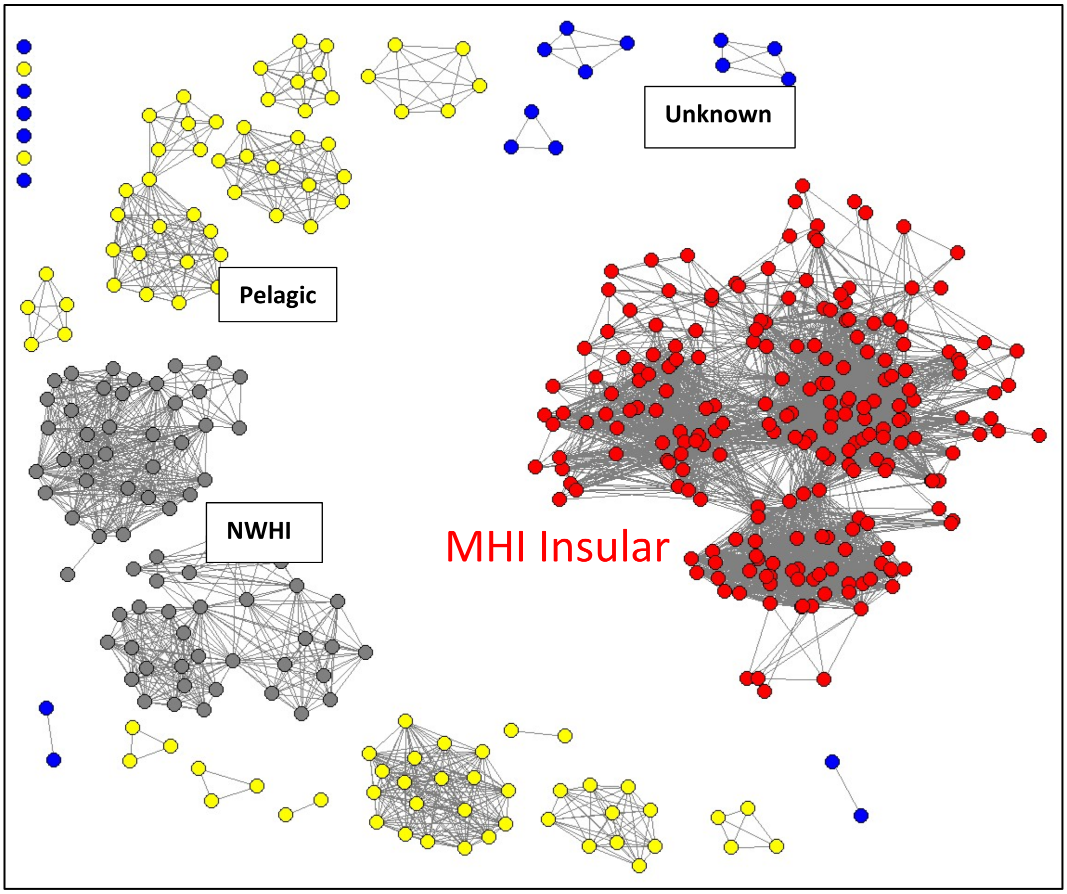

Figure 2–5. Social network diagram of false killer whales in Hawaiʻi from photo-ID data available from 2000 through April 2014. This diagram indicates that MHI IFKWs are socially unconnected with pelagic and NWHI false killer whales. Red represents = MHI IFKW individuals; grey = NWHI; yellow = pelagic; and blue = unknown individuals. (Source: Cascadia Research Collective unpublished data (modified from Baird et al. 2012))

There is significant social structure within MHI IFKWs. Social network analyses once divided MHI IFKWs into three broad social clusters and four small/peripheral clusters based on an analysis of modularity of association data (Newman 2006, Baird et al. 2012); however, as sample sizes increased there was greater ability to resolve whether those peripheral clusters were artifacts or represented real social entities, and a fourth and fifth social cluster have recently been identified (Mahaffy et al. 2017, Robin Baird, Cascadia Research Collective, pers. comm. March 2019) (Figure 2–6). Analyses revealing the fourth and fifth social clusters have not yet been published in detail. Results from Martien et al. (2011) indicate that both males and females exhibit strong site fidelity to natal social groups and that mating occurs both within and between social clusters. Such a mating system could result in inbreeding depression, further constricting the already limited gene flow within the MHI IFKW population.

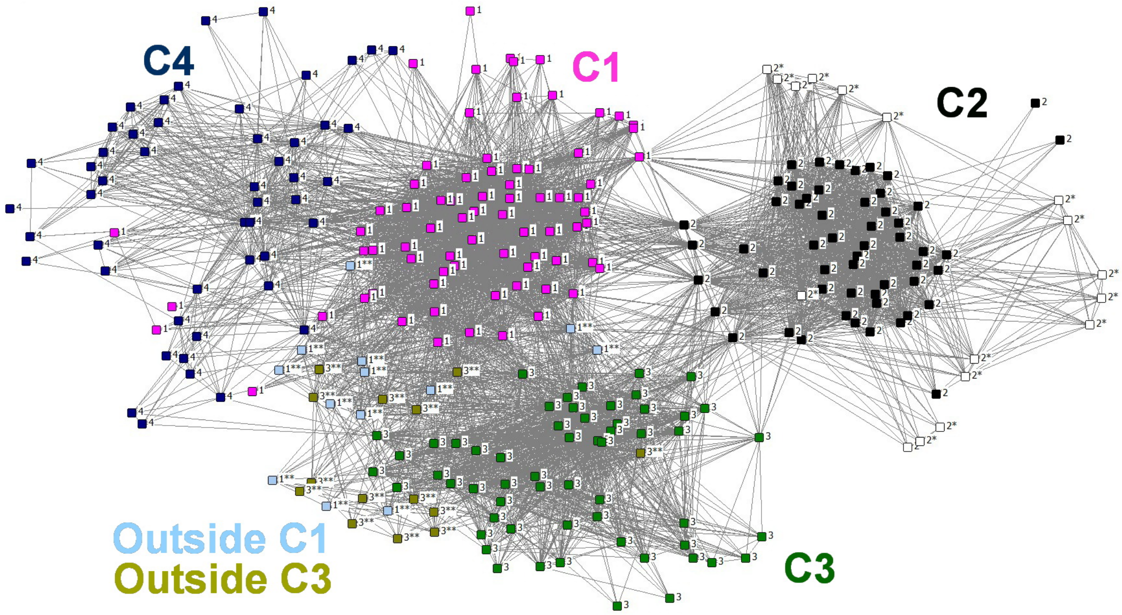

Figure 2–6. Social network diagram of distinctive and very distinctive MHI IFKWs from photo-ID data available from 2000 through March 2018. Cluster 1 – pink; Cluster 2 – black; Cluster 3 – green; and Cluster 4 – navy. The newly-identified Cluster 5 is shown as Outside C1 and Outside C3. (Source: Robin Baird, Cascadia Research Collective, pers. comm. March 2019)

As previously discussed (section 2.3.5.1), studies in Hawaiʻi indicate that MHI IFKWs are most commonly observed in groups of about 10 to 20 animals; these groups may be part of a larger aggregation of subgroups that are dispersed over a wider area (Baird et al. 2008, Reeves et al. 2009, Baird et al. 2010, Oleson et al. 2010, Bradford et al. 2014). Subgroups may be separated by 2–10 km or more, but Baird et al. (2008) noted that over extended encounters (> 4hrs) subgroups would intermix. Baird et al. (2008) describes these large groups as temporary, larger, loose associations of subgroups generally moving in a consistent direction and at a similar speed. These aggregations of subgroups may allow these whales to effectively search a large area for prey and converge when one sub-group locates a prey source (Baird 2009).

2.4.5 Movement

Data show that MHI IFKWs move widely, quickly, and regularly throughout the main Hawaiian Islands (e.g., Baird et al. 2005, Baird 2009, Baird et al. 2010, Baird et al. 2012, Bradford et al. 2015, Baird 2016). The greatest offshore movements occurred on the leeward sides of the islands (114.9 km; Baird et al. 2012). When on the windward sides of the islands, individuals concentrate closer to shore, heavily using areas in the 500 to 1,200 m depth range, particularly north of Hawaiʻi Island, Maui, and Molokaʻi (Baird 2016). Movements between islands may occur over the course of a few days, moving from the windward to leeward side and back within a day (Baird 2009, Baird et al. 2010, Baird et al. 2012). One individual moved from Hawaiʻi to Maui to Lānai to Oʻahu to Molokaʻi, covering a minimum distance of 449 km over a 96-hr period (Baird et al. 2010). Individual MHI IFKWs often demonstrate short- to medium-term preferences for specific island areas before ranging widely among islands and adopting another short-term residency pattern. It is likely that movement patterns of the whales vary over time depending on the density and movement patterns of their prey species (Baird 2009).

2.4.6 Habitat and Habitat Use

One unique and significant attribute of the MHI IFKW is their island-associated nature. The distribution of terrestrial and aquatic communities throughout the Hawaiian Islands, and most of the adjacent Pacific, is largely driven by the prevailing trade winds. Wind-born weather fronts lose some of their moisture passing over the mountainous portions of islands in this region. Thus, windward (northeastern) slopes tend to have higher rainfall than leeward (southwestern) slopes. Windward areas tend to have more wave action and embayments with estuarine development than leeward areas, while leeward areas generally tend to be calmer, dryer, and warmer. The balance between the degree of protection from wind and waves, the amount of rainfall and sedimentation, and the availability of shallow shelf influences the extent of reef development and types of ecosystems in windward and leeward areas (Carlquist 1980). More information on geomorphological and oceanographic features, including Hawaiʻi currents, temporal cycles, eddies, and fronts—all of which can affect attributes of the MHI IFKW preferred habitat such as temperature, productivity of trophic levels, abundance, and distribution of prey species, etc.—is discussed in greater detail in the status review (section 2.2; Oleson et al. 2010) and in the DPS reevaluation (Oleson et al. 2012).

Preferred habitat for MHI IFKWs to forage, socialize, and rest is likely related to the abundance of deep reef slope habitat fringing all of the emergent main Hawaiian Islands, along with a multitude of banks and seamounts. The largest bank, Penguin Bank, is located southeast of Oʻahu, and other notable features in the area include Middle Bank to the northwest of Kauaʻi, and Cross Seamount to the southwest of Hawaiʻi Island.

Analysis of satellite-tagged individuals from all five social clusters suggests different patterns of habitat use within the main Hawaiian Islands. Baird et al. (2012 and 2015a) found three areas of frequent use by MHI IFKWs: the north side of the island of Hawaiʻi (both east and west sides), a broad area extending from north of Maui to northwest of Molokaʻi/east of Oʻahu, and a small area to the southwest of Lānaʻi (Figure 2–7). Habitat use appeared to vary based on social cluster. For example, areas off the north end of Hawaiʻi were only a high-use area for individuals from Clusters 1 and 2, whereas the north side of Molokaʻi was primarily high-use for Clusters 3 and 5 animals, and high-use areas for Cluster 4 were east Oʻahu/northwest Molokaʻi and southwest Lānaʻi (Baird et al. 2012, Baird 2018b). However, new information that further delineates social clusters or provides more insight into seasonal movements may alter these perceived preferences for specific areas as it pertains to social cluster. Tagging data available through March 2018 (n=38 groups) increased the sample size and now includes new information from five clusters (Baird 2018b). Using the methods of Baird et al. (2012), new tagging information indicates that high-use areas extend further west towards Oʻahu and into the channel between Molokaʻi and Oʻahu and off southwestern Lānaʻi (Figure 2–7).

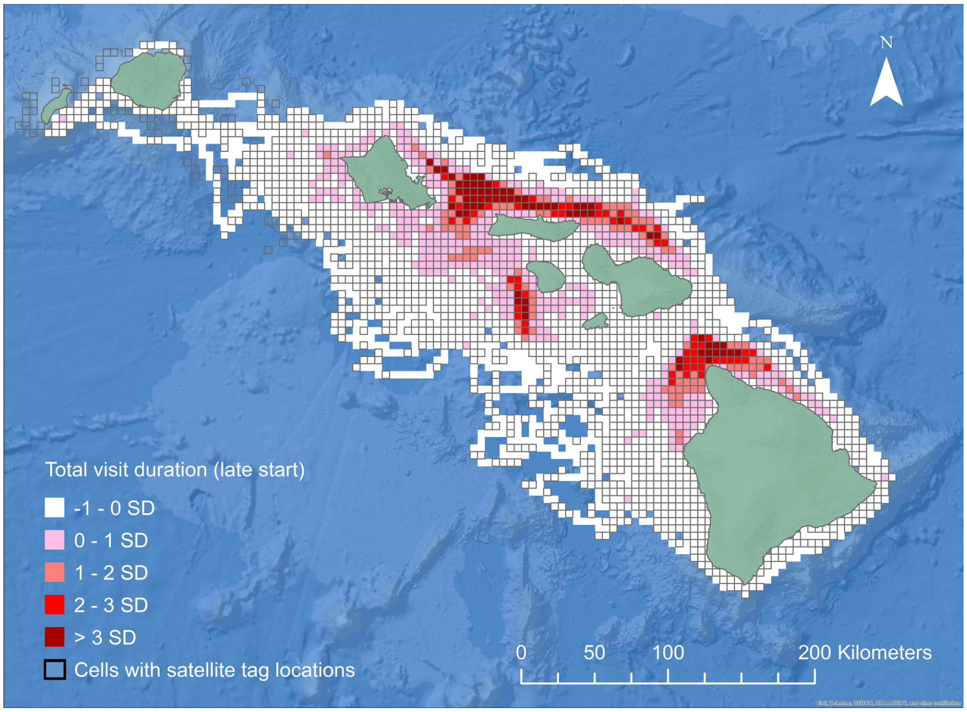

Figure 2–7. MHI IFKW high-use areas by all five clusters representing 38 satellite-tagged individuals through 2018. Map is biased towards Cluster 1, and controlled for pseudoreplication. (This map has been updated by Cascadia Research Collective with the original source as Baird et al. 2012)

Baird et al. (2012) found that tagged MHI IFKWs spent slightly more time on the windward sides of the islands (52.2%) than the leeward sides (47.8%). Chlorophyll-a concentration was significantly higher in high-density cells (cells with high false killer whale occupancy) than in low-density cells. Such higher levels are likely indicative of different oceanographic processes in these areas that enhance productivity. The North Hawaiʻi Ridge Current runs along the north sides of the islands in a northwesterly direction (Qiu et al. 1997), and intersects with two of the large high-density areas, possibly contributing to localized upwelling that may increase productivity.

High-use areas described by Baird et al. (2012 and 2015b) overlap with areas that meet the definition of "biologically important areas"—a term used to identify areas recognized in scientific data as significant as defined by NOAA's CetMap program. CetMap is a mapping tool that is part of NOAA's CetSound program, which aims to improve our ability to visualize cetacean density and distribution and evaluate the effects of man-made noise on cetacean species. Baird et al. (2012) suggested that high-use areas may indicate habitats where MHI IFKWs have increased foraging success and may be particularly important to the conservation of this species. Still, they acknowledged that additional high-use areas could be identified (or current areas further refined) as information is gained from all five social clusters and for all months of the year.

Overall, satellite telemetry data show MHI IFKWs circumnavigate entire islands, use windward and leeward sides approximately equally, though use of windward/leeward waters varies from year to year (Baird 2018b), and they use the area rapidly (i.e., they rapidly move from place to place and do not linger long in one area) (Baird et al. 2010). Individuals also use a broad range of water depths, varying from shallow (<50 m) to very deep (>4,900 m), with the depth distribution for high-use areas more well-defined with a mean depth of 623 m, relative to an overall median depth of 1,679 m. In other words, high-use areas were on average shallower, closer to shore, and with gentler slopes than lower-use areas (Baird et al. 2010, Baird et al. 2012). In fact, analyses from the 38 satellite-tagged individuals (though March 2018) representing all five social clusters further indicates that there is a strong association with island slope and with the 200-m isobath (Baird 2018b). Additionally, a number of areas are considered travel corridors. That is, certain areas may not be high-use areas as defined by the amount of satellite-tag time spent in an area, but the areas are used frequently to transit from one location to another (Baird 2017).

While preferred habitat (i.e., high-use areas) is becoming clearer as more data is analyzed, desirable habitat requirements for MHI IFKWs to breed, give birth, and nurse their young are not well understood. Witnessed breeding and calving events are quite rare, with no instances recorded of false killer whales in the main Hawaiian Islands. There likely is no specific breeding area within the range of the MHI IFKW (Baird et al. 2012).

2.4.7 Diet and Energetic Needs

Several approaches have been used to determine the specific diet of MHI IFKWs; these include predation event observations, fishery depredation data, and stomach content analysis of stranded animals. For MHI IFKWs, predation event observations of prey reveal yellowfin tuna, albacore tuna, skipjack tuna, scrawled file fish, broadbill swordfish, mahi mahi, wahoo, opah, bonefish, lustrous pomfret, threadfin jack, and amberjack as prey items (Baird 2009, Baird, Cascadia Research Collective, 2016 unpublished data). Fishery depredation events in the Hawaiian nearshore troll and longline fisheries have revealed blue marlin, spearfish, and bigeye tuna as prey items (Zimmerman 1983). Longline observer data of fishery depredation events report wahoo, billfish, tuna, moonfish, mahi mahi, pomfret, and lancetfish as prey items (Oleson et al. 2010, NOAA Fisheries Observer Program, unpublished data). Although squid has not been observed during a predation event, analysis of stomach contents of several MHI IFKW has revealed squid beaks (Shallenberger 1981, Tomich 1986, Kristi West, Hawaiʻi Institute of Marine Biology, unpublished data 2016), which comports with squid being reported as false killer whale prey in other areas (Bullis and Moore 1956, Baird et al. 1989, Alonso et al. 1999, Andrade et al. 2001, Hernandez-Garcia 2001). Bait fish have also been found in stomach contents of MHI IFKWs (Kristi West, Hawaiʻi Institute of Marine Biology, pers. comm. 2016). Table 2–1 shows all species reported thus far as dietary items of MHI IFKWs, including the reported sources.

Table 2–1. Species reported as dietary items of MHI IFKWs including the reported sources (as reported in NOAA Fisheries 2017c).

Scientific name	English name	Local name	Reported in
Alectis ciliaris	Threadfin jack	Kagami ulua	Baird 2009
Xiphias gladius	Broadbill swordfish	A‘uku	Baird 2009
*Acanthocybium solandri**	Wahoo	Ono	Baird et al. 2008, Oleson et al. 2010
Aluterus scriptus	Scrawled file fish	Loulu	Baird et al. 2008
Eumegistus illustrus	Lustrous pomfret	Monchong	Baird et al. 2008, Oleson et al. 2010
Katsuwonus pelamis	Skipjack tuna	Aku	Baird et al. 2008
Thunnus alalunga	Albacore tuna	‘Ahi pālaha	Baird et al. 2008
Thunnus albacares	Yellowfin tuna	Ahi	Baird et al. 2008
Coryphaena hippurus	Dolphinfish	Mahi-mahi	Baird et al. 2008, West 2016, Oleson et al. 2010
Serioli dumerili	Amber jack	Kāhala	Baird unpub.
Genus species not determined	Marlin	Species unknown	West 2016
Albula spp	Bonefish	‘O‘io	West 2016, Baird unpub.
Caranx spp	Jack	NA	West 2016
Genus species not determined	Ommastrephid squid	NA	West 2016
Thysanoteuthis rhombus	Diamondback squid	NA	West 2016
Makaira nigricans	Blue marlin	A’u	Zimmerman 1983
Genus species not determined	Spearfish	NA	Zimmerman 1983
Thunnus obesus	Bigeye tuna	Ahi	Zimmerman 1983
Genus species not determined*	Billfish	NA	Oleson et al. 2010
*Lampris regius**	Moonfish	Opah	Oleson et al. 2010, Baird unpub.
Genus species not determined*	Tuna	NA	Oleson et al. 2010
Caranx ignobilis	Giant trevally	Ulua aukea	Baird unpub.
Alepisaurus ferox	Lancetfish	NA	Oleson et al. 2010

Stomach content analysis from the five stranded false killer whales from 2010 to 2016 (all confirmed by genetics to be MHI IFKWs) has provided valuable insight into their diet. All individuals had ~10 to 25 lbs of partially digested prey, 3 to 9 prey items per animal, and 21 total prey items comprising 7 species of relatively large prey. Stomach contents also suggested that squid (diamondback squid, *Thysanoteuthis rhombus,* and squid from the Ommastrephidae family) are important to the MHI IFKWs' diet. The extent of the importance of squid or other top prey such as mahi mahi in the diet of MHI IFKWs is under investigation through further dietary analysis on the stranded individuals. This includes DNA analysis of fecal samples collected from these stranded individuals as well as stable isotope analysis from digested prey (Kristi West, Hawai'i Institute of Marine Biology, pers. comm. 2016).

Other potential approaches to better understand the diet of MHI IFKWs exist. These approaches include predation event samples (e.g., scales and tissue of prey), quantitative assessment of fecal DNA of prey, compound specific stable isotope analysis of prey from biopsied live MHI IFKWs, and contaminant ratios from biopsied live MHI IFKWs.

As previously mentioned, data from dive tags indicate that MHI IFKWs appear to forage both day and night. MHI IFKWs dive deeper than 50 m more than twice as often during the day than they do at night, but they still do have some deep dives at night. Compared to many other cetaceans with dive data (e.g., pilot whales, beaked whales, bottlenose dolphins), MHI IFKWs spend far more time in near-surface waters. Researchers have witnessed >50 predation events by MHI IFKWs, all of which have been fish, and all five social clusters have been documented feeding on game fish (Robin Baird, Cascadia Research Collective, pers. comm. May 2019). There may be cluster-specific differences in diet, but they are likely subtle if they do exist. Examination of stable isotopes from biopsy samples may provide evidence of any large-scale dietary differences by cluster (Robin Baird, Cascadia Research Collective, pers. comm. 2016).

Oleson et al. (2010) determined the energy requirements for MHI IFKWs based on a model developed by Noren (2011) for killer whales. Approximately 2.6 to 3.5 million pounds of fish are consumed annually (based on the 2010 population estimate of 151 MHI IFKWs, depending on the whale population age structure used (see Oleson et al. 2010 for calculation method) (Brad Hanson, NOAA Fisheries Northwest Fisheries Science Center (NWFSC), pers. comm. 2017)). The annual quantity of fish consumed by MHI IFKWs is similar to the current annual retained catch in the commercial troll fishery (~4 million lbs), and is approximately 3 to 4 times greater than the annual catch in the commercial handline fishery (1 to 1.5 million lbs). Recreational fisheries catch varies from year to year but has ranged from 11 to 17 million lbs annually over the last several years based on Western Pacific Regional Fishery Management Council (WPRFMC) annual reports. Therefore, the annual MHI IFKW consumption is far less than the estimated annual catch in recreational fisheries. Additional age structure studies may be able to fine tune this model in the future.

3 THREATS ASSESSMENT

Accurate, up-to-date, and detailed information on threats to the MHI IFKW DPS is critical to informing recovery and conservation activities designed to ameliorate those threats. The final listing rule to list the MHI IFKW as endangered (77 FR 70915) originally described 29 historical, current, and future threats to the MHI IFKW. Careful consideration of these threats since the final listing spurred an updated threats analysis. Ultimately, the original 29 historical, current, and future threats were repackaged into 19 current/future threats (with one historical threat—live capture for aquaria—still listed in the table). We clarified the way the threats were described and grouped some of them for simplicity. For example, instead of separating out the numerous threats related to ocean warming and acidification, we grouped them under the singular threat of "short and long-term climate change." We also described the threats to the MHI IFKW relative to each other rather than describing or listing them based on the ESA's section 4(a)(1) listing factors, resulting in a new ranking scheme.

In the 2010 status review report (Oleson et al. 2010), three categories—high, medium, or low—were used to define the likelihood that each threat will contribute to the decline of MHI IFKWs over the next 60 years. These categories and their definitions were appropriate for the listing process because the goal was to determine the *absolute* level of effect to determine whether or not MHI IFKWs meet the criteria for being listed. However, as we turn our attention and efforts toward recovery, we have determined that it is more appropriate to prioritize threats to the MHI IFKW *relative* to each other so we can determine where and when to invest resources in ameliorating the most significant and urgent threats, relative to the others. Additionally, we have used five categories to better define how the threat is acting on the MHI IFKW relative to other threats. As such, the original definitions of high, medium, and low have been revised using an increasing numeric scale of 1 through 5 to reflect relative concern among the threats. The scale is as follows:

- 1 = Threat of relatively low concern either now or in the future.
- 2 = Threat of relatively low to moderate concern either now or in the future.
- 3 = Threat of relatively moderate concern either now or in the future.
- 4 = Threat of relatively moderate to high concern either now or in the future.
- 5 = Threat of relatively high concern either now or in the future.

According to the revised rating system, we developed a new threat table (based on the original from 2010) to reflect the relative effect of each of the identified threats to the MHI IFKW for the purposes of recovery and conservation actions. Below we address each threat listed in the table by summarizing the existing information and providing updates based on new information. Review the important information in Box A below to understand the definitions of the various parameters listed for each threat in Table 3–1.

Box A. Definitions of parameters used in Table 3–1: Summary of Threats to Main Hawaiian Islands Insular False Killer Whales.

Major Effect: Effect(s) of the threat on a specific aspect of life history or behavior of MHI IFKWs.
Section 4(a)(1) Factor(s): In accordance with section 4(a)(1) of the ESA, a species is listed when it is determined to be endangered or threatened because of any one of the following factors:

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

These factors must also be evaluated when reclassifying or delisting any listed species.

Extent: The portion of the range of the MHI IFKW over which the threat exists.

- *Range wide*: The threat occurs throughout all or the vast majority of the distribution of the MHI IFKW.
- *Localized*: The threat exists primarily in a portion of the range, or may be present at low levels throughout the range but is greatest or most concentrated in one or more discrete areas.

Frequency: The occurrence/regularity of the threat over time.

- *Continuous*: The threat is relatively constant throughout the year.
- *Seasonal*: The threat is greatest during specific seasons, but may occur at other times of the year.
- *Intermittent*: The threat may occur at intervals not associated with specific seasons.
- *Rare*: Infrequent or hypothetical events.

Severity: The magnitude or intensity of a threat across the range of the listed entity (because abundance is so low that loss of an individual could affect the status of MHI IFKWs); described as *low*, *medium*, *high*, or *variable*.

Trend: The change in extent, frequency, or severity of a threat over time; described as *increasing*, *decreasing*, *stable*, or *unknown*.

Relative Concern: The overall perception of how a threat affects MHI IFKW recovery relative to the other threats, on an increasing concern scale of 1 to 5.

Evidence: Level of available information upon which our assessment is based.

- *Clear*: There is clear evidence of the threat acting on MHI IFKWs, based either on observations or on other published or unpublished data.
- *Limited*: There is evidence of the threat occurring within the range of MHI IFKWs, with limited or unclear evidence of its effect on the population and trend; alternatively, there is some evidence that the threat is occurring and affecting MHI IFKWs.
- *Unclear*: There is evidence of an effect that may be caused by this threat, but it is unclear whether or to what extent this threat is the cause of the effect.

Table 3–1. Current and/or Future Threats to MHI IFKWs (listed in descending order of relative concern (i.e., most significant threats listed first)).

Threat (Cause)	Major Effect	ESA Listing Factor(s)	Extent	Frequency	Severity	Trend	Relative Concern	Evidence
Incidental take (hooking or entanglement) in non-longline commercial and recreational fisheries (i.e., troll, handline, kaka line, and shortline)	Injury/mortality	E	Localized	Unknown	High	Increasing	5	Limited
Inadequate regulatory mechanisms (management and reporting) of non-longline commercial and recreational fisheries	Injury/mortality	D	Range wide	Continuous	High	Stable	5	Clear
Small population size	Limited genetic diversity, inbreeding depression, other Allee effects	E	Range wide	Continuous	High	Unknown*	5	Clear
Competition with commercial non-longline fisheries (i.e., troll, handline, kaka line, and shortline)	Reduced prey size and total prey biomass, reduced foraging success, reduced fitness (reproductive and/or survival)	A	Range wide	Continuous	Unknown / potentially high	Unknown	4	Unclear
Competition with recreational fisheries	Reduced prey size and total prey biomass, reduced foraging success, reduced fitness (reproductive and/or survival)	A	Range wide	Continuous	Unknown / potentially high	Unknown	4	Unclear
Environmental contaminants (e.g., PCBs, DDTs, PBDEs, heavy metals, CECs), and naturally occurring biotoxins (e.g., ciguatoxin, algal toxin)	Reduced prey quality and quantity, compromised health, reduced fitness, disease	A, C	Range wide	Continuous	Medium / high	Unknown	4	Clear

Threat (Cause)	Major Effect	ESA Listing Factor(s)	Extent	Frequency	Severity	Trend	Relative Concern	Evidence
Short and long-term climate change (ocean warming, low productivity zones, ocean acidification, and disease vectors (e.g., pathogens, fungi, worms, parasites))	Compromised health, reduced foraging success, reduced fitness (reproductive and/or survival)	A, C, E	Range wide	Continuous	Low / medium	Increasing	**3**	Limited
Anthropogenic noise (e.g., vessel traffic, sonar (military, oceanographic, fishing), alternative energy development)	Reduced communication, reduced foraging success, injury or mortality	A, E	Localized & range wide	Intermittent / continuous	Medium	Stable or increasing	**3**	Limited
Cumulative and synergistic effects	Chronic stress, reduced fitness (reproductive and/or survival) and resilience	A, C, D, E	Range wide	Continuous	Unknown / potentially high	Unknown	**3**	Unclear
Competition with commercial longline fisheries (i.e., deep-set and shallow-set)	Reduced prey size and total prey biomass, reduced foraging success, reduced fitness (reproductive and/or survival)	A	Range wide	Continuous	Unknown / potentially low	Stable	**2**	Unclear
Marine debris ingestion	Compromised health, reduced foraging success, mortality	E	Range wide	Intermittent	Low	Unknown	**2**	Limited
Intentional harm (e.g., shooting, poisoning, explosives)	Displacement, injury, mortality	E	Localized	Rare / Unknown	High	Unknown	**2**	Unclear
Oil spills	Compromised health, reduced fitness, reduced prey quality, mortality	A, E	Localized	Rare	Variable	Stable	**1**	Limited
Predation (killer whales, tiger sharks, etc.)	Injury or mortality	C	Range wide	Rare / Intermittent	Unknown / potentially high	Stable	**1**	Limited

Threat (Cause)	Major Effect	ESA Listing Factor(s)	Extent	Frequency	Severity	Trend	Relative Concern	Evidence
Incidental take (hooking or entanglement) in commercial longline fisheries (i.e., deep-set and shallow-set)	Behavior modification, injury, mortality	E	Localized	Rare	Low	Stable	**1**	Clear
Interactions with aquaculture facilities and other marine structures (e.g., wind farms, solar farms, etc.)	Behavior modification, injury, mortality	E	Localized	Rare	Low	Stable (potential future increase)	**1**	Limited
Vessel strikes	Injury or mortality	E	Range wide	Rare	Low	Stable / increasing	**1**	Limited
Whale/dolphin watching and other ecotours	Behavior modification, displacement, habitat degradation, injury, mortality	E	Localized	Intermittent	Low	Stable	**1**	Limited
Competition with marine species (marlin, sharks, etc.)	Reduced prey size and total prey biomass, reduced foraging success, reduced fitness (reproductive and/or survival)	E	Range wide	Continuous	Low	Unknown	**1**	Unclear
Live capture for aquaria (historic threat)	Reduced population size	B	N/A	N/A	N/A	N/A	0	Clear

**: Thus far we do not have reliable trend information for the MHI IFKW so we cannot determine if the population is increasing (leading to a decreasing trend for this threat), decreasing (leading to an increasing trend for this threat), or stable. Additionally, without reliable trend information, it is difficult to confidently determine the severity of most of the threats.*

3.1 Incidental take in non-longline commercial and recreational fisheries

The threat of incidental take (i.e., interactions like hooking and entanglement) in non-longline commercial and recreational fisheries (i.e., troll, handline, kaka line, and shortline) is rated as a relative concern level of 5, or highest concern. In summary, results from Baird et al. (2017) provide evidence that 1) hooking and entanglement that result in injuries to MHI IFKWs are continuing; 2) both sexes have injuries that are consistent with hooking and entanglement, although there is a significant sex bias towards females in dorsal fin injuries consistent with hooking and entanglement; and 3) mouthline injuries suggest that at least 23% of adult MHI IFKW individuals depredate catch. Due to the scale and distribution of these non-longline fisheries, the prevalence of injuries associated with hooking and entanglement, along with the bias of injuries toward females, the severity of the threat of incidental take in non-longline commercial and recreational fisheries to MHI IFKWs is therefore considered high.

Evidence of MHI IFKW interactions with unidentified hook-and-line fisheries is clear based on scarring and dorsal fin disfigurements (Baird and Gorgone 2005, Baird et al. 2014, Beach 2015, Baird et al. 2017). As reported by Beach (2015), mouthline injuries seen in MHI IFKWs varied widely in severity and frequency, with the most commonly seen injury being large notches in the lip tissue. Two individuals had lip injuries so extensive that lip tissue was completely missing and teeth were visible. Other injuries included irregular pigmentation around the head and lip. Although evidence is clear that these injuries are occurring, evidence of precisely how these injuries are specifically affecting MHI IFKW individuals—from the long-term health and fitness of the individual to the resulting affect to the population—is limited. However, at this time we consider it analogous to the hooking and entanglement of pelagic false killer whales from Hawaiʻi-based commercial longline fisheries where hooking and entanglement injuries are predominantly considered a serious injury. There are differences in injury rates between the MHI IFKW social clusters, suggesting that different social clusters may have different habits that lead to different rates of depredation and hooking and entanglement. Certain behaviors, like depredation and following fishing vessels, may be learned behaviors that are passed down to individuals within a social cluster. These types of behaviors may affect the growth rate of the social clusters differently (Sargeant and Mann 2009, Beach 2015).

Because commercial longline fishing areas only overlap with 5.4% of the MHI IFKWs' range, and these fisheries have 20% and 100% observer coverage for the deep-set and shallow-set fishery, respectively, we have information indicating the interaction rate of commercial longline fisheries with MHI IFKWs is low (Carretta et al. 2018). Therefore, only interactions with non-longline fisheries are discussed here; interactions with longline fisheries are discussed in section 3.15.

Interactions with false killer whales have been reported for troll fisheries (Shallenberger 1981, Zimmerman 1983, Nitta and Henderson 1993), deep-set and shallow-set longline fisheries (Nitta and Henderson 1993, Forney and Kobayashi 2007, McCracken and Forney 2010), and possibly shortline or kaka-line fisheries (anecdotal reports of "blackfish" interactions that may have been false killer whales, cited in Baird 2009). Some recreational fisheries in Hawaiʻi target the same species as commercial fisheries (e.g., tuna, billfish) and use the same or similar gear, and might also be expected to experience interactions with false killer whales. Therefore, non-longline commercial and recreational fisheries managed by the State of Hawaiʻi, including troll, handline, kaka line, and shortline fishing, which overlap spatially with a much greater proportion of the range of MHI IFKWs, are most likely the source of most hooking and/or entanglement. These four fisheries and the nature of reported interactions are very briefly described below, but for a more detailed discussion of each, see Oleson et al. (2010) or see the descriptions of individual fisheries from the online 2020 Final List of Fisheries (LOF) summary table[1].

Based on commercial fishing permits, the troll fishery has by far the greatest participation and effort in fishing days of any fishery within the known range of MHI IFKWs, followed by the handline fishery, with the kaka line and shortline fisheries a distant third and fourth. According to the 2020 Final LOF, the number of vessels/participants (i.e., owners of vessels or gear that are active participants in the fishery) in the commercial troll fishery is estimated at 2,117; the commercial handline fisheries are estimated at 357, 578, and 534 vessels/participants, respectively, for inshore, bottomfish, and pelagic handline; the commercial kaka line fishery is estimated at 15; and the commercial shortline fishery is estimated at 9 vessels/participants (85 FR 21079; April 16, 2020). It is important to note that the State of Hawaiʻi does not issue fishery-specific licenses, and the number of participants reported in the LOF represents the number of commercial marine license holders who reported using a particular fishing gear type/method at least once in a given year, without considering how many times the gear was used. As such, because fishing method is voluntarily reported, there is no way of assessing whether these numbers are representative of actual numbers. For these fisheries, effort by a single participant is counted the same whether the fisherman used the gear only once or every day.

The target species of the troll fishery overlaps with those that make up the MHI IFKW diet, specifically epipelagic species like marlin, mahi mahi, wahoo, and the shallower-swimming tunas such as yellowfin and skipjack. The commercial troll fishery is listed as a Category III fishery under the 2020 Final LOF (85 FR 21079). No incidentally injured or killed false killer whales from commercial troll fishing have been reported to NOAA Fisheries under the MMPA's Marine Mammal Authorization Program (required for fisheries listed on the LOF), and currently there is no independent observer reporting system to document potential marine mammal interactions in the troll fishery. However, there are published reports of depredation by false killer whales in Hawaiʻi-based troll fisheries (Shallenberger 1981, Zimmerman 1983, Nitta and Henderson 1993). Anecdotal reports from New Zealand waters indicate that commercial and recreational troll

[1] The List of Fisheries (LOF), mandated by the MMPA, classifies U.S. commercial fisheries into one of three categories according to the level of incidental mortality or serious injury of marine mammals. The categories are as follows: Category I: *frequent* incidental mortality or serious injury of marine mammals; Category II: *occasional* incidental mortality or serious injury of marine mammals; and Category III: *remote likelihood of / no known* incidental mortality or serious injury of marine mammals. The estimated number of vessels/persons in the 2020 Final LOF for Hawaiʻi state commercial fisheries is based on data provided to NOAA Fisheries by the Hawaiʻi Department of Land and Natural Resources' Division of Aquatic Resources, and represents the number of unique commercial marine license holders that reported using that gear type in the previous year.

fisheries target false killer whales and other delphinids as they are seen as an indicator of the presence of target species such as marlin and tuna. The New Zealand troll fishery is not observed but anecdotal reports of depredation and entanglement of "blackfish" and bottlenose dolphins are not uncommon (Jochen Zaeschmar, Far Out Ocean Research Collective, pers. comm. 2019).

There are three commercial handline fisheries in Hawaiʻi: inshore handline (357 vessels/persons; approximately 3 to 20 miles from shore), bottomfish handline (578 vessels/persons), and pelagic handline (534 vessels/persons; predominantly at weather buoys and the Cross Seamount (Oleson et al. 2010)), and all three are categorized as Category III fisheries under the 2020 Final LOF (85 FR 21079). Palu-ahi and ika shibi—two handline methods associated with the Hawaiʻi pelagic handline fishery—target yellowfin tuna and squid, prime components of the MHI IFKW diet (Yuen 1979, Ikehara 1981, Boggs and Ito 1993). No incidentally injured or killed false killer whales from commercial handline fishing have been reported to NOAA Fisheries under the Marine Mammal Authorization Program (required for fisheries listed on the LOF), and currently there is no independent observer program for Hawaiʻi's commercial handline fisheries. Anecdotal reports, however, indicate that interactions between handline fisheries and cetaceans have been common since at least the 1970s. Bottlenose dolphins or rough-toothed dolphins (*Steno bredanensis*) have generally been implicated rather than false killer whales.

The small-scale kaka line and shortline fisheries—15 and 9 commercial vessels/participants, respectively—use gear similar to longline gear, but with a mainline length of less than 1 nautical mile (nm) and use a greater variety of floats and hooks. Fishermen can have multiple 1 nm lines deployed at one time. Kaka line and shortline sets use up to a few hundred hooks per day in nearshore waters. Kaka lines are set on or near the bottom or in shallow midwater to target a variety of species, including bottomfish, opelu (*Decapturus pinnulatus*), mahi mahi, wahoo, yellowfin tuna, and other nearshore or reef-associated species (WPRFMC 2010). The shortline fishery was developed to target bigeye tuna or lustrous pomfret when they concentrate over the summit of Cross Seamount (290 km (180 mi) south of Hawaiʻi), but it operates in other areas as well. The shortline gear is set before dawn and is retrieved about 2 hours later (74 FR 58879; November 2009). The commercial kaka line fishery is listed as a Category III fishery under the 2020 Final LOF (85 FR 21079). The commercial shortline fishery is listed as a Category II fishery under the 2020 Final LOF (85 FR 21079). No incidentally injured or killed false killer whales from either the commercial kaka line or shortline fishery have been reported to NOAA Fisheries under the Marine Mammal Authorization Program, and currently there is no independent observer program for monitoring bycatch in either fishery. However, there are anecdotal reports of interactions with cetaceans off the north side of Maui, although the species and extent of interactions are unknown (74 FR 58879; November 2009). Based on the similarity of the kaka line and shortline fisheries to longline fisheries (with respect to gear type and target species), it is likely that false killer whales interact with them; however, the nature and extent of any such interactions are unknown. While there is no evidence to suggest a disproportionate threat from the kaka line and shortline fisheries compared with other, much larger fisheries operating within the known range of MHI IFKWs, the shortline fishery is a stationary fishery with multiple catch on the line at once, thus it may be more attractive and rewarding to a false killer whale(s) than a few handlines or moving troll lines. Additionally, anecdotal evidence indicates that some smaller longline vessels that tend to fish closer to the islands might switch to shortline fishing inside the longline exclusion zone, either due to the expansion of the zone year-round, or if there are closures of the Southern Exclusion Zone (see section 4.2). As such, this has the potential to increase the use of longline-type gear inside the MHI IFKWs' range. With the inadequate reporting system for fishing methods (i.e., fishing using multiple methods (e.g., setting shortlines and then fishing handlines while shortlines are soaking) but then only reporting just one method type (e.g., handlining); see section 3.2), it is possible that this type of switch of effort could go completely unrecorded (Robin Baird, Cascadia Research Collective, pers. comm. April 2019).

The prevalence of physical evidence of hooking or entanglement with MHI IFKWs along with the bias of injuries toward females supports the high severity of the threat of incidental take due to fisheries interactions. In fact, as sample size increases of adequate photos of mouthline and dorsal fins, so does the rate of evidence of interactions, indicating the continuation of fisheries interactions over time. Baird et al. (2017) found that 23.3% (17 out of 73 individuals with >50% of mouthline visible in photos of acceptable quality) have mouthline injuries consistent with fisheries interactions (10 females, 4 males, 3 unknown), and 9.1% (15 out of 165 distinctive individuals with good quality photos) of MHI IFKWs have dorsal fin injuries. These results show an increase from earlier studies in which Beach (2015) reported 22% (16 out of 72 individuals) with mouthline injuries consistent with fisheries interactions, and Baird et al. (2014) reported 7.5% of MHI IFKWs (12 out of 160 individuals) with dorsal fin injuries. Interaction rates based on mouthline injuries are likely negatively biased because only 58% of individuals are able to be observed with ≥50% of their mouthline visible (Beach 2015), so some mouth-line injuries are likely concealed below the water during observation and data collection.

In addition to numerous self-reports (Boggs et al. 2015) and videos (e.g., Jouppi 2015) of false killer whale depredation in troll and handline fisheries, examination of a stranded MHI IFKW in October 2013 revealed that this individual had five fishing hooks and fishing line in its stomach (NOAA Fisheries PIR Marine Mammal Response Network, as cited in Carretta et al. 2018). Four of the hooks within the whale's stomach were not consistent with those currently allowed for use within the commercial longline fisheries and could have come from a variety of nearshore fisheries (Baird 2016, Carretta et al. 2018). Although the fishing gear is not believed to have caused the death of the whale, the finding confirms that MHI IFKWs are consuming previously hooked fish or are interacting with hook and line fisheries.

The spatial extent of the threat of incidental take in non-longline fisheries is not well understood; it may occur anywhere there is overlap between non-longline fishing effort and MHI IFKW occurrence. Although analyses show that some fisheries (e.g., shore-based) may have a very limited or negligible chance of overlap with MHI IFKWs, and the probability of interactions between MHI IFKWs and fisheries likely varies dramatically among the islands, there may also be areas with a greater probability of interactions occurring. For example, Figure 3–1 depicts the fishing areas that are also highly used by MHI IFKWs. Eight out of 100 areas are characterized as highly used by MHI IFKWs. These high use areas or "hot spots" are used differently by each social cluster and are between eastern Oʻahu and western Molokaʻi, off Penguin Bank, off northwest Maui, and off the north end of Hawaiʻi Island (State of Hawaiʻi DLNR 2019). There are also concentrated areas of fishing effort as represented by fisheries catch data (reflected by total weight of catch from all non-longline fisheries of all species), which show that areas off the west side of Hawaiʻi Island and nearshore areas around Oʻahu and near Hilo (east side of Hawaiʻi Island) have the highest levels of catch (State of Hawaiʻi DLNR 2019) (see Figure 3–2). While these analyses illustrate that the probability of interactions between MHI IFKWs and fisheries likely varies dramatically among the islands, they are at a coarse level, and include catches from all fisheries, including many of which may have a very limited or negligible chance of overlap with false killer whales (e.g., shore-based fisheries). As such, we need more information on the operations of non-longline commercial and recreational fisheries to better assess the spatial extent, frequency, trend, and severity of this threat. Nonetheless, the best available evidence indicates that incidental take in non-longline commercial and recreational fisheries is one of the most significant threats affecting MHI IFKWs.

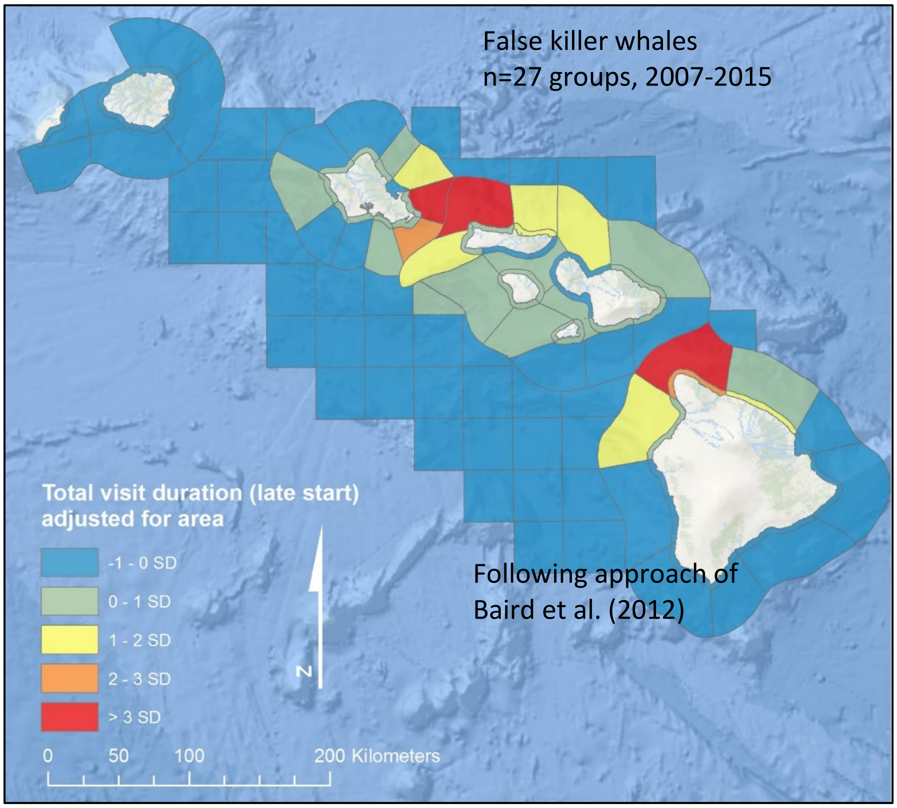

Figure 3–1. High use area of MHI IFKWs by State of Hawaiʻi fishery areas. Data used are from satellite tag deployments by Cascadia Research Collective from 2007 through 2015, using only a single individual from each social group when multiple individuals were acting in concert (see Baird et al. 2012). Approximately 8 of 100 fishing areas are highly used by MHI IFKWs. (Source: State of Hawaiʻi 2016b)

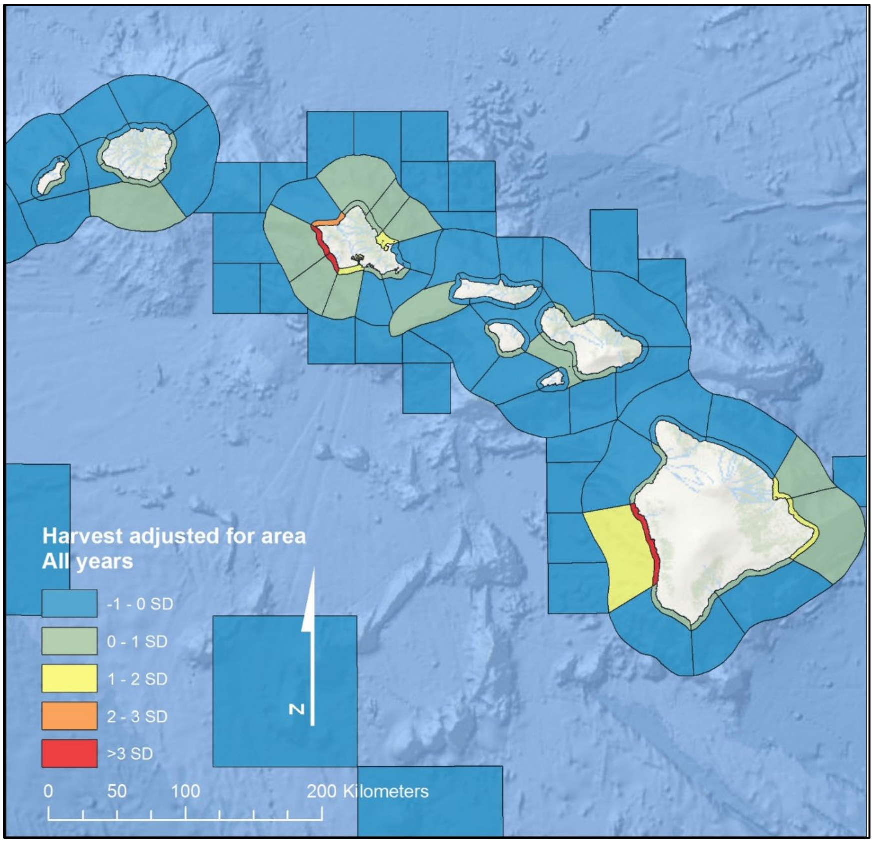

Figure 3–2. Total fisheries catch data (lbs of catch per unit area, shown as standard deviation (SD) above and below the mean), by state fisheries area. This map includes fisheries data from 1994 through 2014 including all seasons. (Source: State of Hawaiʻi 2016b)

3.2 Inadequate management and reporting requirements of non-longline commercial and recreational fisheries

The threat of inadequate regulatory mechanisms for non-longline commercial and recreational fisheries, in the form of inadequate management and reporting requirements, is rated as a relative concern level of 5, or highest concern, because of the evidence that interactions with MHI IFKWs are occurring, coupled with the uncertainties associated with properly assessing and analyzing the mechanisms and effects of these interactions. Specifically, the current reporting requirements for non-longline commercial and recreational fisheries are inadequate to assess the rate and type of interactions occurring with MHI IFKWs. More precisely, fishermen can fish using multiple methods (e.g., set shortlines and then fish handlines while the shortlines are soaking) but then only report just one method type (e.g., handline), thus there is not a good way of assessing the risk for some fisheries. As such, the severity of the threat to MHI IFKWs is considered high.

Inadequate regulatory mechanisms for non-longline commercial and recreational fisheries in the form of inadequate management and reporting requirements is the only threat that has been added to the original 2010 list of threats as a result of feedback and discussions captured at the October 2016 MHI IFKW recovery planning workshop (NOAA Fisheries 2017a) (see the section "Refinement of the originally-described threats facing the species" in the Recovery Outline (NOAA Fisheries 2016) for further explanation). Although related to the first threat described above (incidental take in non-longline commercial and recreational fisheries), inadequate reporting in non-longline commercial and recreational fisheries is itself a threat because inadequate information limits our ability to address and manage the incidental take. The extent of evidence of interactions with non-longline fishing gear was described in section 3.1. A relatively large proportion (23.3%) of MHI IFKW individuals have scarring or other signs of interactions with fishing gear, and this proportion is gradually increasing as the sample size increases (Baird et al. 2017). Yet inadequate information makes it impossible to assess the rate and type of interactions occurring between these fisheries and MHI IFKWs, as discussed below. As a result, the non-longline commercial fisheries are classified as Category III fisheries (*remote likelihood of / no known* incidental mortality or serious injury of marine mammals) on the MMPA LOF except for the shortline fishery, which is classified as Category II by analogy to the commercial longline fisheries.

State commercial fishermen are required to report their catch and other information as part of the requirements for maintaining their commercial marine license (CML); however, the reporting does not collect several types of pertinent information required to accurately characterize both the fisheries (effort detail, catch, precise location, etc.) and the prevalence of interactions with protected species, including the MHI IFKW. In fact, the forms do not require reporting of interactions with any protected species (such as marine mammals or sea turtles). After 2002, report forms included a requirement to list (on a daily basis) catch lost to predators, area fished, and method used. The forms also include a summary entry at the bottom for identification of the predator and total number of fish lost. An analysis by Boggs et al. (2015; cited with permission) found that in many cases, the summary entry on predators included multiple predators that might refer to several different days, areas, or methods. Other caveats noted by the authors explain why the information about predation on catch in these forms should be treated cautiously and has limited utility for inferring interactions (i.e., depredation, hookings, or entanglements) between these fisheries and marine mammals. In addition, many fishermen use various different gear types during a given trip and may only report one as their primary gear type (e.g., trolling to/from the fishing ground where they then use a different gear and only report the primary gear effort and not the trolling gear effort). Moreover, there is a blurry line between commercial catch and non-commercial catch with catch often reported as both (i.e., reported as commercial in a CML report, but also reported as recreational catch in an independent survey), making it difficult to achieve reliable estimates of either one (see Hospital et al. 2011). This analysis shows that marine mammal interactions (i.e., depredation, hookings, or entanglements) occur with these fisheries, but that the information reported on the forms is not informative enough to determine effects to MHI IFKWs or to determine management strategies, since there are different requirements or authorities for regulating commercial versus recreational fisheries. For example, section 118 under the MMPA and its requirements for take reduction plans do not apply to recreational fisheries. Additionally, all commercial fishermen are required to report marine mammal injuries to NOAA Fisheries (per 50 CFR 229.6), but because Category III fishermen are not required to register to receive an Authorization Certificate under the Marine Mammal Authorization Program (per 50 CFR 229.4), Category III fishermen rarely receive information on the reporting requirement or receive a copy of the reporting form that is typically sent with the Authorization Certification. However, even if fishermen had the certificate or the reporting form, information from interactions (i.e., depredation, hookings, or entanglements) might not be submitted to NOAA Fisheries because self-reporting rates are often very low. A prime example of this is in the commercial longline fisheries where oftentimes reports are not received from unobserved trips. This indicates that the solution is not simply to merely include reporting requirements because fishermen do not report bycaught animals at rates anywhere near what the observer data show.

Improving the reporting completeness and accuracy in state commercial fisheries and implementing a reporting requirement for non-commercial fisheries is necessary to better understand effects from several of the highest-concern threats to the endangered MHI IFKW. It would also allow for development of cooperative management with fishermen to reduce interactions. Accurate and detailed catch reporting can assist in understanding the true nature of both direct and indirect effects of fisheries on MHI IFKWs and vice versa. Evidence of fishing gear injuries to MHI IFKWs indicates that hooking and entanglement are relatively common and are continuing to occur (as new injuries are often recorded (Baird et al. 2017)), but we are unable to adequately assess and analyze the extent, frequency, and severity of hooking and entanglement given limitations in data from the CML reporting forms, or to develop management or mitigation measures if needed. In addition to hooking and entanglement, these fisheries may be in competition with MHI IFKWs for their primary prey species, as described in more detail below.

3.3 Small population size (limited genetic diversity, inbreeding depression, and other Allee effects)

The threat of small population size is rated as a relative concern level of 5, or highest concern. Reliable trend information for the MHI IFKW is not available so it is difficult to determine whether small population size may be an increasing, decreasing, or stable threat. The severity of the threat is considered high. The only way to address this threat is to create circumstances that allow for the population size to increase by addressing, mitigating, minimizing, or eliminating other threats to MHI IFKWs.

Similar to many imperiled species, MHI IFKWs face demographic obstacles that may slow or even impede recovery, including small population size. The most recent abundance estimate for 2015 was 167 (SE=23; 95% CI=128–218) animals in the surveyed area, with annual estimates over a 16-year survey period from 2000 to 2015 ranging from 144 to 187 animals for the portion of the range surveyed in each year (Bradford et al. 2018). The current minimum population estimate for the MHI IFKW is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al. 1995) of the 2015 abundance estimate (from Bradford et al. 2018), or 149 false killer whales. According to Martien et al. (2019), there is an estimated effective population size of 57.6 individuals (95% CI=47.2–71.8). Effective population size is affected by many factors over multiple generations and although the 2015 population estimate of 167 individuals in the surveyed area is slightly higher than the 2010 estimate of 151 individuals, we do not know to what extent effective population size can change (Karen Martien, NOAA Fisheries SWFSC, pers. comm. March 2018).

The processes that cause small populations to have a greater risk of extinction include genetic and behavioral problems, as well as chance processes like demographic and environmental stochasticity (Shaffer 1981, Gilpin and Soule 1986, Goodman 1987, Simberloff 1988, Lande 1993). The decrease in per capita population growth as population size declines is often referred to as the “Allee effect” or “depensation” (e.g., Allee 1931, Allee et al. 1949, Dennis 1989, Fowler and Baker 1991, Courchamp et al. 1999, Stephens and Sutherland 1999, Stephens et al. 1999, Petersen and Levitan 2001, Dennis 2002, Berec et al. 2007). In essence, as the number of individuals decreases, there are costs from a lack of predator saturation, impaired anti-predator vigilance or defense, a breakdown of cooperative feeding, an increased possibility of inbreeding depression or other genetic issues, decreased birth rates as a result of not finding mates, or a combination of these effects. The Allee effect increases risk to small populations directly by contributing to the risk of extinction, and indirectly by decreasing the rate of recovery of exploited populations and, therefore, maintaining populations at a smaller size where extinction risk is higher for a variety of reasons (e.g., environmental or demographic stochasticity) (Dennis 1989, Stephens and Sutherland 1999).

In addition, social odontocetes (such as false killer whales) may be particularly vulnerable to threats over and beyond the numerical loss of individuals to the population (Wade and Reeves 2010). Some of these effects may act in a similar fashion to Allee effects or have a more pronounced effect at low population sizes. Survival and reproductive success may depend on such things as social cohesion and social organization, mutual aid in defense against predators, and possible alloparental care (i.e., care from an individual other than the biological parent of an offspring) such as “babysitting” and communal nursing, sufficient opportunities for transfer of “knowledge” (learned behavior) from one generation to the next, and leadership by older individuals that know where and when to find scarce prey resources (e.g., during El Niño events) and how to avoid high-risk circumstances (e.g., stranding, predation).

False killer whales share several life history traits with killer whales and beluga whales that make them prone to problems associated with small population size: a low intrinsic growth rate (a consequence of late maturity and a low birth rate), strong social structure demonstrated through close associations of individuals over long time periods, the potential for high adult survival enabled by the intergenerational transmission of certain types of awareness or specialized behavior, and a low effective population size compared to abundance. This last feature leads to low genetic diversity, which increases the probability that inbreeding depression (a decrease in birth or survival rates resulting from deleterious or lethal genes) will occur at a higher level of total abundance than is the case for many other species. Franklin (1980) found that inbreeding depression increases substantially when the number of reproductive animals becomes fewer than 50. Given that the total adult population of MHI IFKWs (including individuals that are reproductively senescent) is probably around 72 (167 estimated individuals in the 2015 surveyed area (Bradford et al. 2018) times 43% of which are mature (based on killer whales, Taylor et al. 2008), it could be approaching the level at which the effects of inbreeding depression become a factor in determining whether the population is able to maintain itself or increase. The estimate of an effective population size of about 57.6

breeding adults (Martien et al. 2019) makes the potential for loss of genetic diversity in the near future a concern.

A small population could also experience a breakdown of social functionality important to fecundity and survival. Although some aspects of the behavior and “culture” of MHI IFKWs have been investigated or discussed, the mechanisms by which they might influence population growth rates are not well understood. The situation of this population could be analogous to those of other populations of large mammals in which females live well beyond their reproductive life spans (e.g., elephants, higher primates, and some other toothed cetaceans such as pilot whales) (McComb et al. 2001, Lahdenpera et al. 2004). The loss of only a few key individuals such as the older, post-reproductive females could result in a significant loss of inclusive fitness conveyed by “grandmothering” behavior (i.e., assistance in care of the young of other females in the pod). In addition, cultural knowledge (e.g., how to cope with environmental changes occurring on decadal scales) could be lost, leading to reduced survival or fecundity of some or all age classes. Wade and Reeves (2010) document the special vulnerability of social odontocetes giving examples of killer whales, beluga whales, sperm whales, and dolphins in the eastern tropical Pacific.

The threat of small population size represents a high risk to MHI IFKWs because the current estimated number of breeding adults is approaching levels where inbreeding depression could have increasing negative effects on population growth rate and because other social factors (such as efficiency in group foraging and potential loss of knowledge needed to deal with unusual environmental events) may further compromise the ability of MHI IFKWs to recover to healthy levels. Considering these aspects of the MHI IFKW population—confined range, genetic isolation, social complexities, and limited abundance—the recovery potential of the MHI IFKW is concerning.

3.4 Competition with commercial non-longline fisheries

The threat of competition with commercial non-longline fisheries (i.e., troll, handline, kaka line, and shortline) is rated as a relative concern level of 4, or moderate to high relative concern. Stocks of prey species are wide ranging and the amount of overlap between non-longline fishing activity and the range of the MHI IFKW is important in terms of competition for the locally available fish. Catches by local fisheries inside the range of MHI IFKWs represent removal of prey that compete locally in “real time” (i.e., ecological interaction) with foraging whales. Both fisheries and the whales disrupt the local prey aggregations and remove the immediately available local fish. The biomass of the removed fish is replaced by longer-term reproduction and growth, as well by immigration. All of the latter processes are thought to be dominated by the overall size of the fish populations which extend far beyond the range of Hawaiʻi fisheries and MHI IFKWs, and are not influenced much by either, since they remove such a small proportion of the total biomass of the wide-ranging prey populations (Boggs 1994, He and Boggs 1996, 1997). Commercial (and recreational) troll and handline fisheries in Hawaiʻi operate almost entirely within the MHI IFKWs’ core nearshore habitat (<40 km from shore). The commercial troll and handline fisheries alone now harvest as much or more than is estimated to be consumed annually by MHI IFKWs. (The annual catch from commercial kaka line and shortline fisheries is not reported in the annual stock assessment and fishery evaluation reports (e.g., WPRFMC 2017a). While their level of harvest and thus level of competition with MHI IFKWs is unknown, because of gear type and fishing location, both fisheries are surmised to compete for prey with MHI IFKWs.) Recreational non-longline fishing also harvests much more than is estimated to be consumed annually by MHI IFKWs and is discussed in more detail in section 3.5. Prey of MHI IFKWs includes many of same species targeted by Hawai'i's commercial non-longline fisheries, especially tuna, billfish, wahoo, and mahi mahi. The annual magnitude of prey required by MHI IFKWs is estimated to be 2.6 to 3.5 million lbs/yr (Brad Hanson, NOAA Fisheries NWFSC, pers. comm. 2016). Troll fishermen harvested between 3 and 4 million lbs/yr in 2014 and 2015 (Figure 3–3), and the handline catch was 1 to 1.5 million lbs/yr for those years (Figure 3–4) (WPRFMC 2017a).

Competition with commercial non-longline fisheries may be present range wide and continuously. Past trends in local prey removal by fisheries are indicated by an increase in troll and handline catch from the early 1970s to the mid-1980s. It should be noted that the species composition for the troll and handline catches has changed since the late 1980s when skipjack tuna catch increased and yellowfin tuna decreased, although yellowfin catches have been higher in the last five years for which we have data. The commercial troll fishery remains a very active potential competitor in the MHI IFKWs' habitat (see Figure 3–3). Commercial handline catches seem to be most variable compared to other fishing types, with wide oscillations in the 1970s and 1980s, a spike in catch in 1999, followed by a decline to about a third of the 1999 catches by around 2008, and a more recent increase in the last five years for which we have data (see Figure 3–4).

In summary, the potential competition of commercial non-longline fisheries with local foraging by MHI IFKWs as indicated by the catch of the local commercial troll fishery has increased since the early 1970s, although the increase has slowed in recent decades. Competition from the commercial handline fishery would seem to have diminished compared to the late 1990s (with a recent upswing), although it, too, has increased considerably since the early 1970s. How changes in competition align with the likely decrease in MHI IFKW abundance is currently unknown. There is no direct evidence that competition is resulting in the whales being food limited, and there are no known observations of whales in reduced body condition that could be an indication of poor nutrition. Any current trend in the frequency of competition with commercial non-longline fisheries that may affect MHI IFKWs is also unknown, given a lack of clear overall trends in current catch within the habitat. However, the severity of the threat of competition with commercial non-longline fisheries is considered unknown but potentially high.

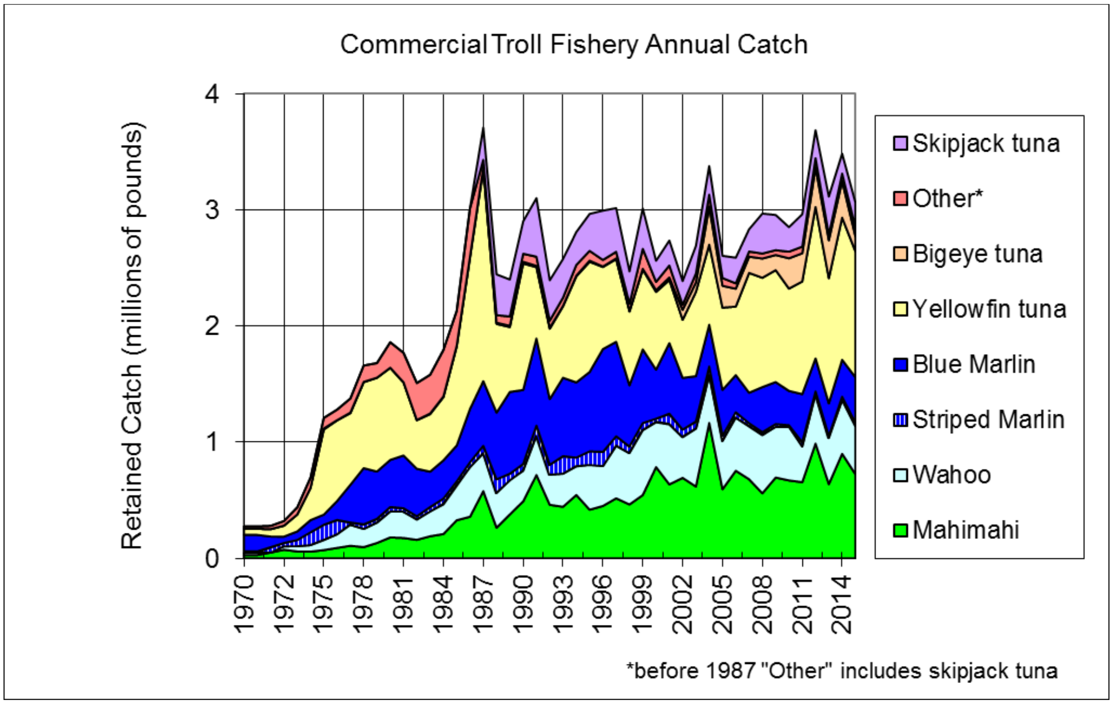

Figure 3–3. Long-term annual catch in Hawai'i's commercial troll fishery from 1970 through 2015. (Source: Boggs and Ito 1993, WPRFMC 2010, Oleson et al. 2010, WPRFMC 2017a)

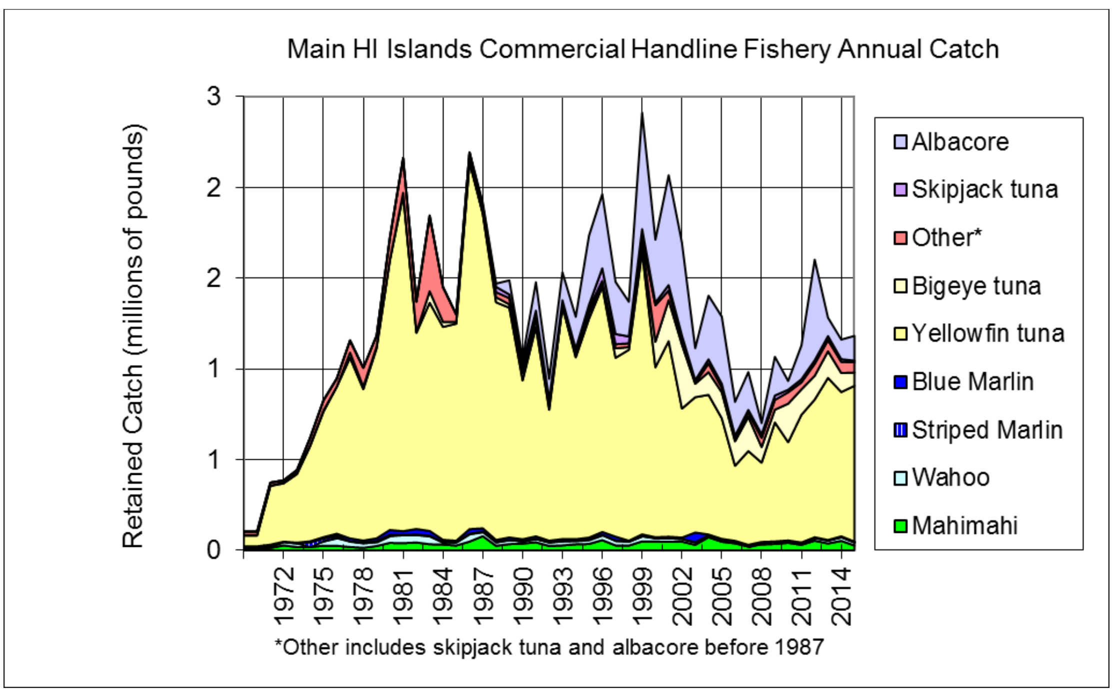

Figure 3–4. Long-term annual catch in Hawai'i's commercial handline fishery from 1969 through 2015. (Source: Boggs and Ito 1993, WPRFMC 2010, Oleson et al. 2010, WPRFMC 2017a)

Prey Abundance as Reflected in Catch-per-unit-Effort

Trends in catch and catch-per-unit effort (CPUE) are assumed to reflect trends in abundance of these fish species, with reduced biomass representing a potential threat to MHI IFKWs. The CPUE of fisheries that overlap the range of MHI IFKWs represents an index of the local and more widespread availability of prey, and reflect much broader effects of Pacific-wide fishing mortality and other factors on the forage base.

A primary assumption in most ecosystem approaches to understanding multispecies population dynamics is that prey biomass fluctuations have a strong influence on predator populations (Kitchell et al. 1999). The inference is that both fishery removals of potential prey in the immediate vicinity of false killer whales (competition) and long-term declines in prey biomass over the range of the fish stocks (declining CPUE and biomass) may both represent potential threats to MHI IFKWs. The discussions of catch (above) and CPUE make this assumption.

The troll fishery shows declining total CPUE from the late 1970s to the mid-1980s, with some stability through the mid-2000s, and a more recent increase in the last few years for which we have data, due mostly to yellowfin tuna and mahi mahi (Figure 3–5). The handline CPUE shows less trend but suggests a sharp increase during the 1970s, followed by a decline through 2008, but a more recent increase due to catch of yellowfin tuna in the last several years of data (Figure 3–6). The handline fishery CPUE is dominated by tuna catches with little catch of other species. The CPUE data from the Hawai'i longline fishery (see section 3.10) shows the greatest decline from the 1950s through the mid-1970s, as do stock assessments (e.g., Davies et al. 2014). These time series all indicate major declines in abundance of tunas and other wide-ranging prey species many decades ago, with less-clear trends in recent times, including some increases.

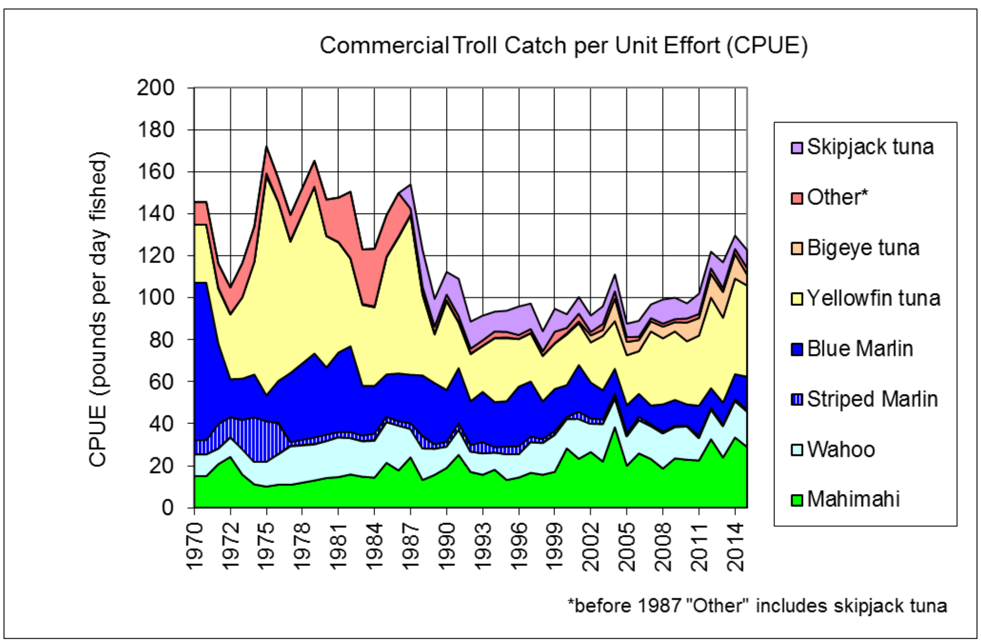

Figure 3–5. Long-term CPUE in Hawai'i's commercial troll fishery from 1970 through 2015. (Source: Boggs and Ito 1993, WPRFMC 2010, Oleson et al. 2010, WPRFMC 2017a)

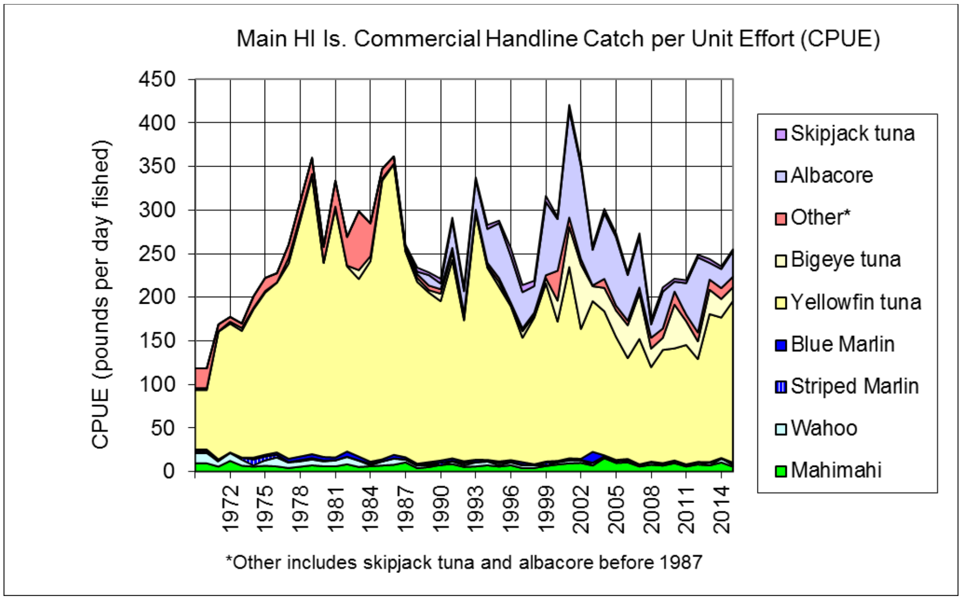

Figure 3–6. Long-term CPUE in Hawai'i's commercial handline fishery from 1969 through 2015. (Source: Boggs and Ito 1993, WPRFMC 2010, Oleson et al. 2010, WPRFMC 2017a)

Prey Size

Troll and handline fish sizes show some increase for about the last decade as a result of increased billfish sizes (Figure 3–7). These size data are reflected in the CPUE data as well, as these were presented in weight per unit of effort.

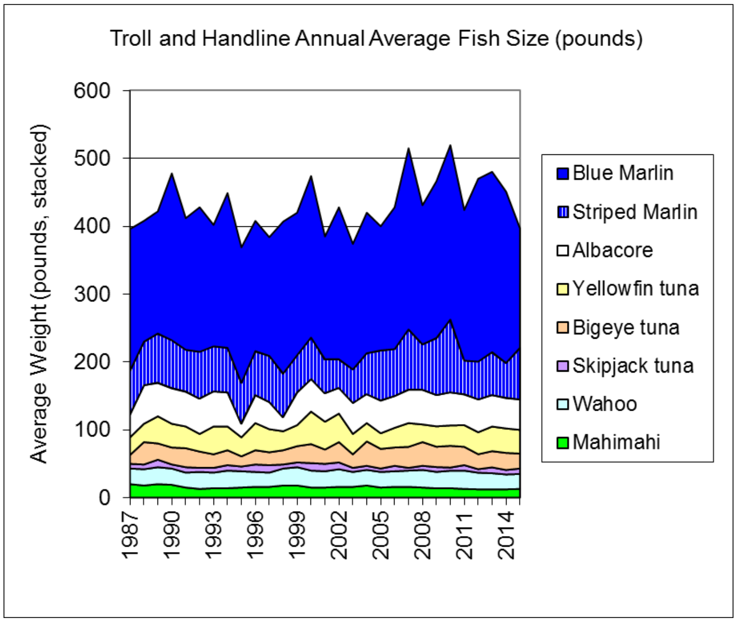

Figure 3–7. Average fish size caught in Hawai'i's commercial troll and handline fisheries between 1987 and 2015. (Source: WPRFMC 2010, Oleson et al. 2010, WPRFMC 2017a)

3.5 Competition with recreational fisheries

Another potential source of competition for prey biomass is from recreational (non-commercial) fisheries. The threat of competition with recreational fisheries is rated as a relative concern level of 4, or moderate to high relative concern. Competition with recreational fisheries may be present range wide and continuously. Any trend in the frequency of competition from recreational fisheries that may affect MHI IFKWs is unknown, and the severity is considered unknown but potentially high.

The level of concern for this threat—moderate to high relative concern—is highly uncertain because there is no reporting system in place to accurately record the level of catch or trend of target species in recreational fisheries. Recreational catch data come largely from voluntary surveys and other social science techniques that have a variety of caveats, therefore giving the results high uncertainty (see Ma and Ogawa 2016). The best available estimate of pelagic species catch in recreational fisheries is an average of 13.5 million lbs/yr for 2003 to 2014 (Ma and Ogawa 2016). Extrapolated recreational fish catch totals are many times higher than reported commercial catch totals for troll and handline fisheries. If nominal recreational fish estimates are representative, then the recreational sector would represent almost three times as much competition for fish as the reported commercial non-longline fisheries. Recall that the annual magnitude of prey required by MHI IFKWs is estimated to be 2.6 to 3.5 million lbs/yr (Brad Hanson, NOAA Fisheries NWFSC, pers. comm. 2016), and annually, recreational fishing harvests almost four to five times as much fish as all endangered MHI IFKWs combined. As noted earlier, there is some overlap in the catch that gets reported as commercial catch via CML reporting requirements and catch that gets reported in a survey of non-commercial catch making it difficult to tease out the separate effects of competition from these different types of fisheries (see Hospital et al. 2011).

3.6 Environmental contaminants and naturally occurring biotoxins

The threat of environmental contaminants and naturally occurring biotoxins is rated as a relative concern level of 4, or moderate to high relative concern. Contaminants and biotoxins may be present range wide and continuously. Because of their high trophic status, whales are often exposed to high levels of contaminants that biomagnify through the food web, and are exposed over a long life-span, including vulnerable life history stages. Changes to population dynamics resulting from this exposure will be slow to appear because of slow maturation rates and the likely slow recovery of compromised health (Rowe 2008). Any trend in the concentration of contaminants and biotoxins that may affect MHI IFKWs is unknown, but the severity of the threat to the DPS is considered medium/high.

Exposure to toxic chemicals, including persistent organic pollutants (POPs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethanes (DDTs), polybrominated diphenyl ethers (PBDEs), heavy metals, and chemicals of emerging concern (CECs) is a potential risk factor of moderate to high relative concern for MHI IFKWs (e.g., Fallon 2009, Ylitalo et al. 2009, Oleson et al. 2010, Bachman et al. 2014, Foltz et al. 2014, Kratofil et al. 2020). Each class of chemicals can cause a suite of health effects to MHI IFKWs as discussed below, with more specific information provided in Oleson et al. (2010).

Foltz et al. (2014) analyzed blubber biopsies from 10 species of live wild Hawaiian odontocetes, including 33 MHI IFKWs, collected in 2009 and 2010 and found concerning results. Total PCB (a type of POP) concentrations in 84% of the sampled MHI IFKWs exceeded the suggested 14,700 ng g^{-1} threshold for risk of maternal failure (Schwacke et al. 2002) and 71% exceeded the proposed ≥17,000 ng g^{-1} threshold for thyroid and immune system disruption in aquatic animals (Kannan et al. 2000). Additionally, total PCBs correlated with cytochrome P4501A1 expression (CYP1A1—a biomarker of exposure and molecular effects of certain POPs) indicates that the individual is responding to contaminant exposure at the molecular level, potentially resulting in negative physiological consequences. The authors also found significantly higher levels of CYP1A1 were observed in MHI IFKWs and rough-toothed dolphins compared to melon-headed whales (*Peponocephala electra*), and, in general, trophic position appears to influence CYP1A1 expression patterns in particular species groups. Moreover, while no significant differences in CYP1A1 were found based on age class or sex across all samples, within male MHI IFKWs, juveniles expressed significantly higher levels of CYP1A1 when compared to adults. Finally, differences in CYP1A1 expression among MHI IFKW social clusters were examined but no significant findings were reported; however, knowledge of social clusters at the time of the study was limited (Foltz et al. 2014).

A contemporary study by Kratofil et al. (2020) extends the information reported by Ylitalo et al. (2009) and Foltz et al. (2014) by providing a greater sample size (66 more biopsies), updated life history information for biopsied individuals, social cluster assignments, and biopsies of NWHI and pelagic false killer whales. The authors found that pollutant levels were similar among populations, although MHI IFKWs had a significantly higher mean ratio of DDTs/PCBs than NWHI whales. The total PCB concentrations of 28 MHI IFKWs (68%) sampled were equal to or greater than suggested thresholds for deleterious health effects. Trends in POP concentrations among age/sex class for MHI IFKWs follow what was speculated by Ylitalo et al. (2009), which is adult females contain lower concentrations of POPs than those found in adult males, and lower than (for PCBs) or roughly equal to (for DDTs) subadults. This difference is significant because it further supports that females off-load some of their contaminants to their offspring. Additionally, 8 of the 24 adult females have never been documented to give birth (based on sighting histories) and thus could either be post-reproductive or possibly first-born calves and therefore could have started with high body loads that could have had reproductive consequences (Robin Baird, Cascadia Research Collective, pers. comm. April 2019). The mechanisms of effect and sources of contaminants are briefly described below, but more detail can be found in Oleson et al. (2010).

Additional findings from Kratofil et al. (2020) include: the highest POP values among samples were found in four stranded MHI IFKWs; juvenile and sub-adult MHI IFKWs had lower levels of most contaminants compared to adults, but elevated levels of PBDEs, dieldrin, and hexachlorobenzene; and POP classes and concentrations vary by MHI IFKW social cluster. This last finding suggests that MHI IFKW social clusters likely forage in different areas around the Hawaiian Islands—reinforcing findings from satellite tag studies (Baird et al. 2012, 2019)—and may be subject to varying degrees of exposure to certain POP classes. These findings could also reflect variability in the types of prey these groups primarily consume, however stable isotope results would provide a more distinct indication of this inference as they more directly reflect what is consumed (Kratofil et al. 2020).

In marine mammals, exposure to high levels of "legacy" POPs has been associated with immunosuppression (Ross et al. 1995, Beckmen et al. 2003), reproductive dysfunction (Helle et al. 1976, Subramanian et al. 1987), and morphological changes (Zakharov and Yablokov 1990, Sonne et al. 2004). "Legacy" POPs include a number of chemical classes (e.g., PCBs, DDTs, mirex, chlordane) that were used as industrial chemicals and pesticides in the United States and other countries around the world. These compounds tend to biomagnify in marine ecosystems, especially in lipid-rich tissues of top-level predators (McFarland and Clarke 1989). Although banned in the United States and many other areas in the early 1970s, PCBs, DDTs, and other classes of POPs continue to be used in other regions of the world and can be transported via atmospheric transport or ocean currents (Fiedler 2008, van den Berg 2009) and thus continue to be measured in marine animals from Hawaiʻi (Hunter 1995, Kimbrough et al. 2008, Ylitalo et al. 2009, Foltz et al. 2014) and other portions of the United States (Kannan et al. 2004, Wells et al. 2005, Krahn et al. 2007, West et al. 2008, Krahn et al. 2009) and pose a potential risk to their health.

Exposure to PBDEs has been associated with a number of biological effects (e.g., thyroid disruption, neurobehavioral effects, and reproductive dysfunction) in laboratory animals (de Wit 2002, Talsness 2008). PBDEs are used as flame-retardants in manufactured goods including textiles, automobiles, and electrical components (de Wit 2002). Similar to PCBs, these compounds are persistent and lipophilic, and they have been measured in samples of air, dust, sediments, and tissues of fish, marine mammals, and humans collected from many regions of the world (de Wit 2002, Shaw and Kannan 2009). However, no threshold PBDE values have been established for toxic effects in marine mammals.

Heavy metals (e.g., mercury, cadmium, lead, aluminum, nickel) have been shown to accumulate in marine mammals and, in some cases, may cause deleterious biological effects, including alterations in steroid synthesis and liver damage (O'Hara and O'Shea 2001), and infection by opportunistic fungal invaders (Mouton et al. 2015). Of greatest concern for marine mammals are mercury, lead, cadmium, and the organotins. These substances could pose risks to MHI IFKWs as they have been found in relatively high concentrations in false killer whales from other regions of the world. Currently, no data on heavy metals are available for MHI IFKWs so the risk associated with exposure to these substances is unknown.

With human population growth and increasing commercial development, there has been an increased demand for industrial chemicals, current-use pesticides, pharmaceuticals, and personal care products. The term used for many of these new substances is CECs, or chemicals of emerging concern. Unfortunately, an overwhelming number of high-volume industrial compounds are not being monitored currently in biota as few analytical methods have been developed to measure them in tissues. Currently, it is unclear what risk CECs pose to MHI IFKWs or their habitat as little is known about the current occurrence, fate, and transport of CECs in waters of the main Hawaiian Islands.

One concern for MHI IFKWs is that reduced prey quantity or quality could increase the risk associated with exposure to any of these chemicals. For example, it is suspected that body condition can influence POP burdens in the blubber of marine mammals even though the dynamics of blubber POPs during changes in physiological condition of these animals are complex and poorly understood (Aguilar et al. 1999). Marine mammals can lose weight during various stages of their life cycles because of stresses such as disease, migration, or reduced prey abundance. The mobilization of lipid associated with weight loss could result in redistribution of POPs to other tissues, or to retention of these compounds in blubber that would result in a concentration increase (Aguilar et al. 1999). Thus, animals that are nutritionally challenged could be at higher risk because of increased mobilization of these compounds to other organs where damage could result.

Regarding biotoxins in the environment, single-cell organisms, such as dinoflagellates, constitute the base of the marine food web and some of these organisms are responsible for the production of biotoxins associated with harmful algal blooms (HABs). Blooms of these organisms are attributed to two primary factors: natural processes (such as circulation, upwelling relaxation, and river flow) and anthropogenic loadings leading to eutrophication (Sellner et al. 2003). From 1998 to 2008, HABs were documented in every coastal state of the United States and these events appear to be increasing in frequency and geographical distribution worldwide (Hellegraeff 1993, Sellner et al. 2003, Lopez et al. 2008). Biotoxins associated with blooms have been shown to accumulate in fish, shellfish, and top-level predators such as marine mammals and humans (Hellegraeff 1993, Trainer 2002). Over the past 30 years, a number of marine mammal stranding events have been associated with HABs. Marine mammals can be exposed to biotoxins through ingestion of toxin-contaminated prey or through inhalation of seawater. Exposure to these compounds can cause a variety of symptoms including muscular paralysis, confusion, seizures, memory loss, and death (Trainer 2002). Biotoxin exposure has been implicated in the mass strandings and deaths of California sea lions (*Zalophus californianus*; Scholin et al. 2000), humpback whales (*Megaptera novaeangliae*) (saxitoxin), and manatees (*Trichechus manatus*) (brevetoxin) in the United States (Geraci et al. 1989, Oshea et al. 1991, Bossart et al. 1998, Flewelling et al. 2005).

Ciguatoxin is one of the most commonly occurring biotoxins in subtropical and tropical regions of the world (Lehane and Lewis 2000). However, information on ciguatoxin poisoning in marine mammals from the Hawaiian Islands is scarce. For example, the only reported ciguatoxin-related mortality event involved the deaths of several Hawaiian monk seals from Laysan Island in 1978. Ciguatoxin and maitotoxin exposure were proposed to be the cause of the seal deaths as high levels of these biotoxins were measured in their livers (Gilmartin et al. 1980). No data on ciguatoxin levels in MHI IFKWs or their primary prey are available. Thus, the potential risk posed by this biotoxin to MHI IFKWs from the main Hawaiian Islands is not known.

3.7 Short and long-term climate change

We combined climate change-related threats identified in Oleson et al. (2010) and the final listing rule (including ocean warming-related increases in low productivity zones, ocean acidification, and the potential increase in disease vectors (e.g., pathogens, fungi, worms, parasites) associated with warming) into one threat for purposes of recovery planning. The threat of short and long-term climate change is rated as a relative concern level of 3, or moderate relative concern. Effects from short- and long-term climate change may be present range wide and continuously. The severity of the threat to MHI IFKWs is currently considered low/medium, though this could change in the future since the trend in the effects from climate change that may affect MHI IFKWs is anticipated to increase in the long-term.

As described in more detail below, there are limited published data on disease occurrence in false killer whales, let alone an increase in disease vectors due to climate change, but some documented disease cases exist (e.g., liver disease, dolphin rhabdovirus-like virus, porpoise morbillivirus). Species that live in close-knit social groups like MHI IFKWs have greater potential for transmission of certain pathogens such as morbillivirus. Climate change has been implicated as a cause of the variation in the prevalence and severity of disease outbreaks within marine ecosystems (Harvell et al. 2009). Multiple factors are likely to contribute to these changes including the expansion of pathogen ranges in response to warming, changes to host susceptibility because of increasing environmental stress, and the expansion of potential disease vectors (Hoegh-Guldberg et al. 2010).

Ocean temperature plays a key role in determining pelagic habitat for many species, and changes in this parameter would likely have a strong effect on false killer whales. Many prey species and competitor species of MHI IFKWs have ranges closely linked to ocean temperature, both isotherms and gradients. Changes in epi-pelagic habitat predicted by modeling include increasing temperatures, declining zooplankton densities (Polovina et al. 2011, Boyce et al. 2014), changes in species richness, and changes in carrying capacity (Woodworth-Jefcoats et al. 2015). For false killer whales, many of their forage species are migratory and/or mobile (i.e., few benthic species). The movement of other large predatory marine species' ranges is likely to change, which could affect competition with false killer whales. However, a much better understanding is needed of prey preferences and predator-prey dynamics before speculating on the possible impacts of warming or cooling trends on MHI IFKWs.

Increases in low-productivity areas (e.g., Polovina et al. 2008, Brewer and Peltzer 2009) would probably have the strongest effect on false killer whales. Lower productivity resulting in a decrease in forage abundance would have a negative effect, unless mobile forage species were concentrated into smaller regions that could then be exploited more easily. Again, presumed effects are large but net directionality is difficult to predict.

Ocean acidification can lead to changes in marine ecosystem productivity and community composition. Effects of ocean acidification on false killer whales remain speculative. Acidification, per se, is unlikely to influence growth, mortality, or reproduction in false killer whales given their well-insulated endoskeletons, physiological/biochemical modulation of pH, and the ability to relocate to other areas if acidification has strong spatial patterning. However, a large unknown is whether MHI IFKWs would remain in the same location if conditions became less favorable. Climate change-related ocean acidification could alter productivity and composition of the main Hawaiian Islands ecosystem (Guinotte and Fabry 2008). For example, increased CO_2 levels is thought to significantly affect the abundance of epipelagic squid (Fabry et al. 2008) and thus is likely of particular relevance to false killer whales. Net effect on higher trophic levels remains unclear, yet is likely negative. Shifts in pelagic species composition could have many direct and indirect effects on distribution and abundance of large pelagic predators.

Since the mid-1960s, the number of published reports that examined protozoa, parasites, bacteria, viruses, and harmful algal toxins in marine mammals has increased greatly (e.g., Gulland and Hall 2007, Bossart 2011, Ulrich et al. 2016, Barbieri et al. 2018, Jo et al. 2018). In Hawaiʻi, five MHI IFKWs stranded between 2010 and 2016 and were screened for diseases. All five were negative for the common culprits including toxoplasmosis, *Brucella*, morbillivirus, herpes virus, and adenovirus. Other marine mammals in Hawaiʻi have died from toxoplasmosis based on necropsy findings, including at least 3 spinner dolphins (Migaki et al. 1990, Angela Amlin, NOAA Fisheries PIRO, pers. comm., May 2020) and at least 13 Hawaiian monk seals (Angela Amlin, NOAA Fisheries PIRO, pers. comm., May 2020). This indicates that marine mammals in Hawaiʻi can be exposed and susceptible to these types of diseases. There is more information available for false killer whales as a species, along with other cetaceans, which is summarized in Oleson et al. (2010).

Duignan et al. (1995) noted that species that live in close-knit social groups (e.g., false killer whales) would have greater potential for pathogen transmission (this study was on morbillivirus in western Atlantic false killer whales). In a study by Guimarães, Jr. et al. (2007), network theory in killer whales showed that the combined effects of topology (i.e., the distribution) and strength of social links among individuals increased vulnerability to disease outbreaks. The authors suggested that even individuals that live in small, isolated groups may be threatened to disease outbreaks that may affect almost the entire population. The authors noted that in natural conditions, the transmission of disease is probably compensated by the benefits derived from social interactions, such as hunting efficiency and food sharing. However, the same may not be true in reduced populations in which the immunity of individuals is already challenged by contaminant loads or facing recently introduced pathogens (Guimarães, Jr. et al. 2007). Lastly, Gaydos et al. (2004) conducted a literature search of infectious diseases in odontocetes and determined that marine *Brucella* spp., cetacean poxvirus, morbillivirus, and herpesviruses would pose the greatest threat to the ESA-listed Southern Resident killer whales. Based on similarities in life history strategies (e.g., long life span, time to maturation, cohesive social group), it is likely that exposure to these pathogens also poses a risk to MHI IFKWs.

Various parasites have been documented in tissues of false killer whales, including nematodes (e.g., *Anisakis simplex*, *Stenurus globicephalae*), trematodes (e.g., *Nasitrema globicephalae*), acanthocephalans (e.g., *Bolbosoma capitatum*), amphipods (e.g., *Isocyamus delphinii*, *Syncyamus aequus*, *Syncyamus pseudorcae*), and crustaceans (e.g., *Xenobalanus globicipitus*) (Sedlak-Weinstein 1991, Stacey et al. 1994, Andrade et al. 2001, Hernandez-Garcia 2002, Zylber et al. 2002). In some cases, parasitic infections have been implicated as contributing to false killer whale strandings (Odell et al. 1980, Morimitsu et al. 1987). Currently, no information is available on the aforementioned parasites in MHI IFKWs.

In the 2010 status review (Oleson et al. 2010), the biological review team listed cookie cutter sharks (*Isistius brasiliensis*) as a predator of MHI IFKWs. However, because this small (~50 cm) shark, which feeds by biting off small chunks of much larger animals, is deemed a parasite rather than a predator (i.e., it feeds off larger animals without killing them), we believe the threat from this species is more appropriate under parasitism and therefore we include it here. Although photographs document parasitism by cookie cutter sharks on MHI IFKWs, these circular wounds are likely to be superficial and not cause serious injury or mortality. A possible exception to this would be a newborn calf if the wound was on the belly and penetrated into the body cavity (as has occurred on a spinner dolphin; see Baird 2016). As with any open wound, however, there is always the remote potential for infection that may spread. Dwyer and Visser (2011) note a maximum of 150 days between open wound and healed scar in killer whales with cookie cutter shark bites. Duration between open wound and healed scar from cookie cutter shark bites on MHI IFKWs is unknown.

3.8 Anthropogenic noise (e.g., vessel traffic, sonars, alternative energy development)

Certain anthropogenic sounds have the potential to interfere with the acoustic sensory system of false killer whales. Effects from anthropogenic sounds can be physiological (e.g., causing permanent or temporary hearing loss), or acoustically mask biologically important sounds (e.g., communication, navigation), or cause behavioral effects (e.g., changes to feeding, nursing, resting, or abandonment of habitat). Therefore, the threat of anthropogenic noise is rated as a relative concern level of 3, or moderate relative concern. The extent of the effects from noise may be localized or range wide depending on the action/source, and the frequency of occurrence is intermittent or continuous, depending on the source such as ongoing operations of alternative energy generation. The trend in frequency of the threat from noise is stable or increasing, and the severity of the threat to MHI IFKWs is considered medium.

Odontocetes, including false killer whales, have a highly evolved acoustic sensory system. False killer whales rely heavily on their acoustic sensory capabilities for navigation, foraging, and communication. Potential and measured effects of anthropogenic noise on cetaceans have been reviewed by a number of authors (e.g., Richardson et al. 1995, Hildebrand 2005, Weilgart 2007). The information we have regarding effects of noise on false killer whales comes from research done on captive animals (e.g., Thomas and Turl 1990, Yuen et al. 2005, Nachtigall and Supin 2013); we currently do not have information on the effects of sound on false killer whales in the wild.

Certain anthropogenic sounds such as vessel noise, sonar, underwater construction, and alternative energy development can interfere with false killer whales' acoustic sensory systems. Effects can include permanent or temporary hearing loss; masked reception of navigation, foraging, or communication signals; and disrupted reproductive, foraging, or social behavior. Experiments on a captive false killer whale have revealed that it is possible to disrupt echolocation efficiency in this species, with the level of disruption related to the specific frequency content of the noise source as well as the magnitude and duration of the exposure (Mooney et al. 2009). Experiments on this same captive animal have also revealed that a false killer whale can reduce its hearing sensitivity when a loud sound is preceded by a warning sound (Nachtigall and Supin 2013). These results may prove to be valuable in the practical protection of cetacean hearing. Short, loud anthropogenic noises placed in the animals' environment might be partially mitigated by providing less intense warning sounds before the loud sound is received by the animal, thus allowing the whale to proactively change its hearing sensitivity for protection (Nachtigall and Supin 2013).

Increasing numbers and speeds of vessels in areas with cetaceans may have the cumulative effect of reducing habitat quality by increasing the underwater noise level. Noise from small vessels can significantly mask acoustically-mediated communication in delphinids and contribute to the documented negative effects on animal fitness (Jensen et al. 2009). Jensen et al. (2009) demonstrated that free-ranging delphinids in a coastal deep-water habitat are subjected to varying and occasionally intense levels of vessel noise. Vessel noise and sound propagation measurements from a shallow-water habitat were used to model the potential effect of high sound levels from small vessels on delphinid communication in both shallow and deep habitats, with bottlenose dolphins and pilot whales as model organisms. The authors found that small vessels traveling at 5 knots in shallow water can reduce the communication range of bottlenose dolphins within 50 m by 26%. Pilot whales in a quieter deep-water habitat could potentially suffer a reduction in their communication range of 58% caused by a vessel at similar range and speed. Increased cavitation noise at higher speeds drastically increases the effect on the communication range. Gear shifts generate high-level transient sounds (peak–peak source levels of up to 200 dB re 1 µPa) that may be audible over many kilometers and may disturb close-range animals.

Per the Hawaiʻi Tourism Authority's (HTA) 5-year Strategic Plan, which calls for continued growth of Hawaiʻi's visitor industry (HTA 2016), the number of visitors to the islands will likely increase. An increase in tourism will therefore increase the demand for unique Hawaiian experiences, many of which involve boat traffic (whale watching, deep sea fishing, etc.).

In recent years, there has been increasing concern that active sonar and seismic operations are harmful to beaked whales (Cox et al. 2006) and other cetaceans, including melon-headed whales (Southall et al. 2006) and pygmy killer whales (*Feresa attenuata*) (Wang and Yang 2006). The use of active sonar from military vessels has been implicated in mass strandings of beaked whales, and recent mass-stranding reports suggest some delphinids are affected as well. A 2004 mass stranding of melon-headed whales in Hanalei Bay on the Island of Kauaʻi occurred during a multinational sonar training event around Hawaiʻi (Southall et al. 2006). Although data limitations preclude a conclusive finding regarding the role of Navy sonar in triggering this event, sonar transmissions were considered a plausible, if not likely, cause of the mass stranding. This conclusion is based on the spatiotemporal link between the sonar exercises and the stranding, the direction of movement of the transmitting vessels near Hanalei Bay, and propagation modeling suggesting the sonar transmissions would have been audible at the mouth of Hanalei Bay (Southall et al. 2006). False killer whales have been herded using loud sounds in drive fisheries off Japan (Kishiro and Kasuya 1993, Brownell et al. 2008), suggesting that high-intensity noise can affect the behavior of false killer whales in Hawaiian waters.

The U.S. Navy Hawaiʻi Range Complex encompasses most of the known range of the MHI IFKW and employs sonar from the unit-level to multi-strike group exercises that broadcast high-intensity, mid-frequency sonar sounds (U.S. Navy 2008). Southall et al. (2016) reviewed recent field experiments studying cetacean responses to simulated or actual active military sonars and report highly variable responses. They note that differences among species and individuals along with contextual aspects of exposure appear to affect the probability of response, making it difficult to predict responses based on simple acoustic metrics. The specific location and timing of mid-frequency sonar training activities near Hawaiʻi is inconsistent from year to year; the Department of Defense consults with NOAA Fisheries on their training activities but few details are provided regarding the timing, frequency, or location of the sonar-related activities due to national security concerns. As such, it is not possible to predict the frequency of occurrence of sonar use within the range of the MHI IFKW over time.

Other sources of anthropogenic noise include other types of sonars (e.g., associated with research, fishing), seismic surveys, and noise from alternative energy development. Vessel traffic can also increase noise levels in the marine environment. Seismic surveys used for hydrocarbon exploration are unlikely around Hawaiʻi; seismic exploration associated with research is, however, possible. Indeed, in August of 2018, NOAA Fisheries issued an incidental harassment authorization to Lamont-Doherty Earth Observatory to incidentally take, by Level B harassment, MHI IFKWs during a marine geophysical survey in the North Pacific Ocean (83 FR 44578) since the survey area included designated critical habitat for MHI IFKWs. However, studies completed to date near the Hawaiian Islands use seismic receivers to map ocean areas based on natural seismic activity without generating artificial sound (Cao et al. 2011, Rychert et al. 2013), so noise associated with seismic research is not likely of much concern for MHI IFKWs.

Noise from constructing and operating alternative energy sources, such as floating wind or wave energy facilities, is also a relatively new potential source of noise in Hawaiʻi. According to the Bureau of Ocean Energy Management—Hawaiʻi website, in 2015, the agency received three unsolicited wind energy lease requests. The projects propose offshore floating wind energy facilities 9–17 miles off southern and northwestern Oʻahu in water depths of approximately 300–1000 m with energy transmitted to Oʻahu by undersea cables (www.boem.gov/Hawaiʻi). Effects from up and coming alternative energy development to cetaceans in Hawaiʻi is not yet available but could include habitat avoidance, temporary behavioral disturbance, etc., based on effects to proxy species elsewhere (e.g., North Sea, Baltic Sea) (e.g., Bailey et al. 2010, Middel and Verones 2017). Since these projects will require a federal permit or funding, potential effects to marine life including ESA-listed MHI IFKWs and their critical habitat will be analyzed during the ESA section 7 consultation process.

3.9 Cumulative and synergistic effects

The threat of cumulative and synergistic effects is rated as a relative concern level of 3, or moderate relative concern. The extent of cumulative and synergistic effects is range wide with continuous frequency. The trend in frequency of cumulative and synergistic effects is unknown and the severity of the threat to MHI IFKWs is unknown/potentially high.

There are many examples of how the threats to MHI IFKWs could potentially work synergistically and therefore with increased severity or frequency. As previously discussed in the contaminants section (section 3.6), reduced prey quantity or quality could increase the risk associated with exposure to lipophilic POPs. It is suspected that body condition can influence POP burdens in the blubber of marine mammals even though the dynamics of blubber POPs during changes in physiological condition of these animals is complex and poorly understood (Aguilar et al. 1999).

Marine mammals can lose weight during various stages of their life cycles as a result of stresses such as disease, migration, or reduced prey abundance. The mobilization of lipids associated with weight loss could result in redistribution of POPs to other tissues, or to retention of these compounds in blubber that would result in a concentration increase (Aguilar et al. 1999).

Causes of reduced prey size and total prey biomass may be due to a combination of factors acting synergistically including competition with fisheries, competition with natural competitors, and climate change. Reduced prey availability may also lead to a shift in targeted prey species, which may require greater energy expenditure to forage and/or may carry an increased toxic load. As such, these factors may act both directly and indirectly on MHI IFKWs.

Although both rated as lowest concern threats, whale and dolphin watching and vessel strikes may act synergistically since increased vessel traffic from whale and dolphin watching and ecotours could lead to more vessel strikes. The Hawaiʻi Tourism Authority's 5-year Strategic Plan calls for continued growth of Hawaiʻi's visitor industry (HTA 2016). As the number of visitors to the islands increases, demand for unique Hawaiian experiences, many of which involve boat traffic (whale watching, deep sea fishing, sunset cruises, etc.), is likely to increase as well.

These are just a few examples of how several of the identified threats to MHI IFKWs can act synergistically to have negative effects on individuals and the population overall. We need a better understanding of many of these threats to fully understand the potential for cumulative and synergistic effects among them.

3.10 Competition with commercial longline fisheries (i.e., deep-set and shallow-set)

The threat of competition with commercial longline fisheries is rated as a relative concern level of 2, or low to moderate relative concern. Primary prey for MHI IFKWs includes many of the same species targeted by Hawaiʻi commercial longline fisheries, especially tuna, billfish, wahoo, and mahi mahi. Stocks of these prey species are wide ranging and the amount of overlap between fishing activity and the MHI IFKWs' range is important in terms of competition for the locally available fish.

The Hawaiʻi-based commercial deep-set and shallow-set longline fisheries combined landed ~40 million lbs of fish in 2015, which is up ~13% from 2014 (WPRFMC 2017a,b). In 2016, ~37 million lbs of fish were landed, and in 2017, ~39 million lbs of fish were landed (an increase of ~6% from the previous year) (WPRFMC 2018a). In 2018, ~38 million lbs of fish were landed (a ~4% decrease from the previous year) (WPRFMC 2018b). However, only 5.4% of the MHI IFKWs' range currently overlaps with active commercial longline fishing area (see Figure 2–3 and Figure 2–4). A total of 2.6 to 3.5 million lbs/yr is the estimated magnitude of prey required by the present-day MHI IFKWs (Brad Hanson, NOAA Fisheries NWFSC, pers. comm. 2016).

Competition with commercial longline fisheries for potential prey within the MHI IFKWs' range seems to have represented a higher risk prior to the early 1990s when longline fisheries were harvesting many millions of pounds of fish per year (Figure 3–8), and where reported longline locations were almost all in what is now the longline exclusion zone (LLEZ; see Figure 2–4)

(Oleson et al. 2010). In those years through the early 1990s, direct competition with commercial longline fisheries was likely more severe. Since the 1992 closure of the LLEZ, direct competition with commercial longline fisheries has decreased. However, the annual removal of ~37–40 million lbs of potential false killer whale prey in direct proximity to known MHI IFKW prime habitat would likely affect prey availability in these adjacent areas given the prey's documented high level of mobility. Therefore, relative concern is rated as low to moderate, the extent of the threat is range wide, the frequency is continuous, and the severity of the threat of competition with commercial longline fisheries to the DPS is considered unknown but potentially low with a stable trend.

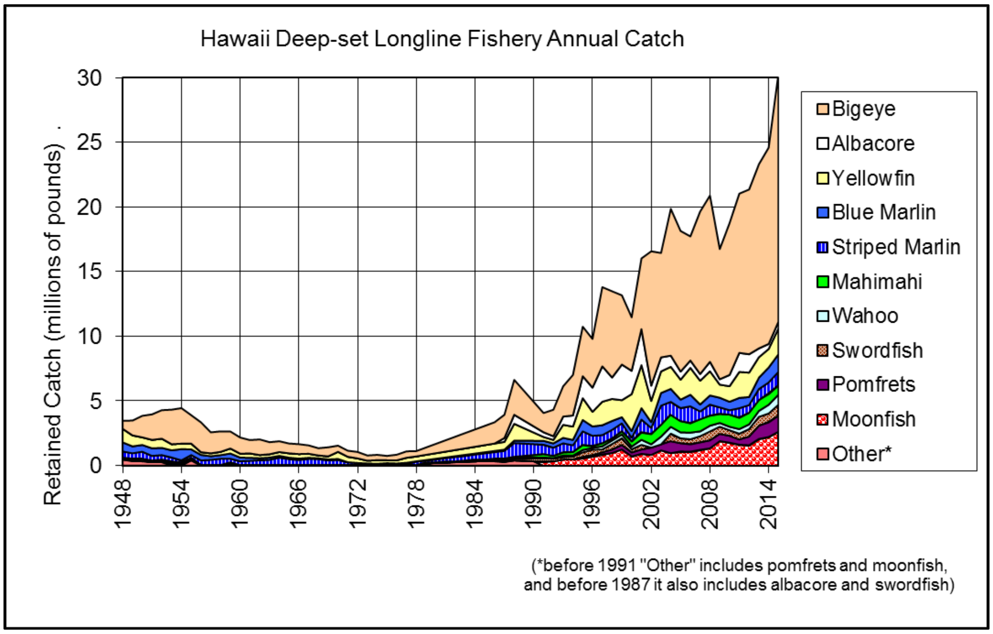

Figure 3–8. Long-term annual catch in the Hawaiʻi deep-set longline commercial fishery from 1948 through 2015. (Source: Boggs and Ito 1993, WPRFMC 2010, Oleson et al. 2010, WPRFMC 2017a)

Prey Abundance as Reflected in Catch-per-unit-Effort

The annual catch and CPUE data trends of longline fishing (discussed above) imply different potential threats to MHI IFKWs (see Figure 3–8 and Figure 3–9). First, the catches by local fisheries inside the known range of MHI IFKWs represent removals that compete locally in "real time" (i.e., ecological interaction) with foraging whales. Both fisheries and the whales disrupt the local prey aggregations and remove the immediately available local fish. Second, the CPUE of fisheries that overlap the range of MHI IFKWs represents an index of the local and more widespread availability of prey, and reflects much broader effects of Pacific-wide fishing mortality and other factors on the forage base both in terms of biomass and size of fish.

After a sustained and major decline in abundance from the 1950s through the mid-1970s, the Hawaiʻi deep-set longline CPUE data suggest some overall increases in abundance of target species from the mid-1980s into the 1990s, followed by a decline after 1997 and some slight increase since 2009 (Figure 3–9). The CPUE time series indicates local availability of prey to natural predator populations or to local fisheries, both of which cannot find anywhere near the abundance of fish that they could prior to the 1990s or earlier, based on data presented here. The downward trends in target species abundance since the 1990s are less steep than in the earlier decades, and CPUE for some species appears to have stabilized or increased a bit since 2009 (Figure 3–9). Although declines in prey biomass were more dramatic in the past when MHI IFKW population size may have been larger, the total prey abundance remains very low compared to the 1950s and 1960s, as evidenced by biomass estimates from tuna stock assessments (Davies et al. 2014). For yellowfin tuna, the most recent stock assessment (Davies et al. 2014) projects future biomass increases. For both bigeye and yellowfin tuna, projections based on the most recent fisheries statistics from 2013 to 2015 (Pilling et al. 2016) indicate increasing biomass for yellowfin tuna, and no further biomass declines for bigeye tuna, if recent levels of recruitment are assumed to continue.

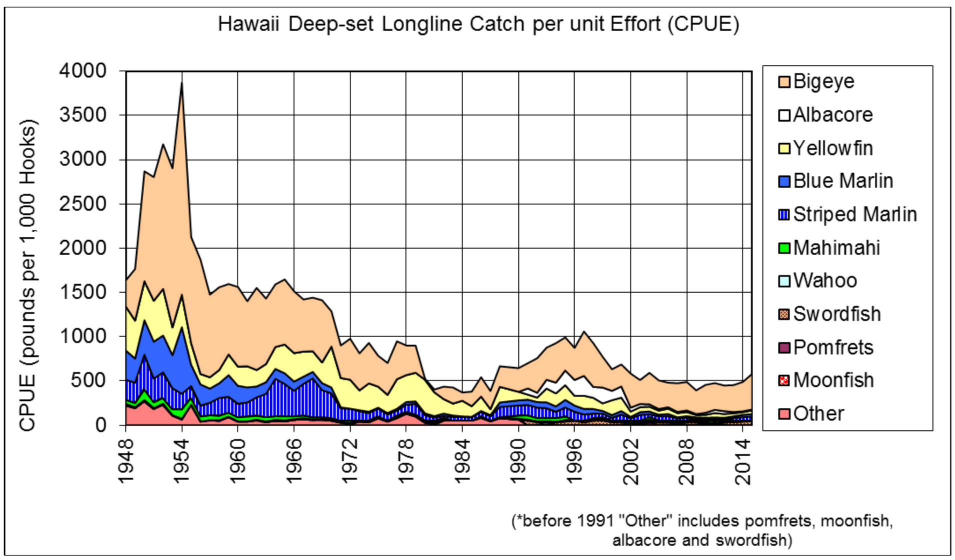

Figure 3–9. Long-term CPUE in the Hawaiʻi deep-set longline fishery between 1948 and 2015. (Source: Boggs and Ito 1993, Oleson et al. 2010, WPRFMC 2010, WPRFMC 2017a)

Prey Size

Yellowfin and bigeye tuna average weights seem to have declined between each of the periods of data available for the Hawaiʻi longline fishery, with the greatest decline in tuna size happening between the early 1950s and late 1960s (Figure 3–10). Data on average fish weight in Figure 3–9 are taken from Shomura (1959) for 1949–1954, from Yong and Wetherall (1980) for 1965–1977, the Pelagics Annual Report (WPRFMC 2010) for 1987–2008, and from the 2015 Pelagic SAFE report (WPRFMC 2017a) for 2009–2015 (Figure 3–10).

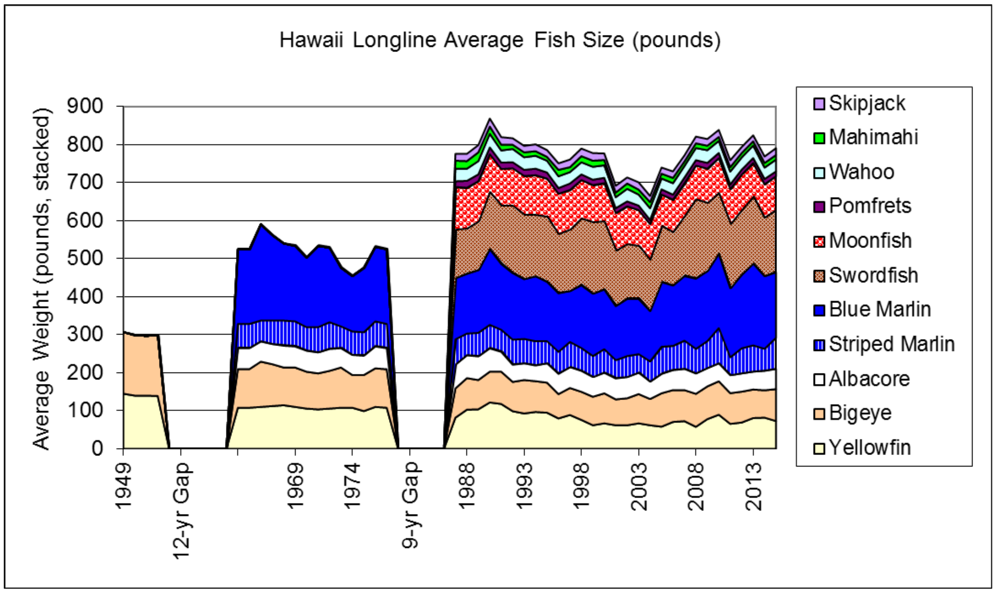

Figure 3–10. Long-term average fish size caught in Hawai'i's longline fisheries. (Source: Shomura (1959) for 1949–1954, from Yong and Wetherall (1980) for 1965–1977, the Pelagics Annual Report (WPRFMC 2010) for 1987–2008, and from the 2015 Pelagic SAFE report (WPRFMC 2017a) for 2009–2015)

The biological effect of smaller prey for MHI IFKWs is that there is less energetic reward per successful predation event, which leads to more time (energy) spent foraging. On the other hand, smaller and therefore younger prey may carry lower levels of contaminants. Compounding the problem is that overall reduced prey biomass means that MHI IFKWs need to spend more time foraging (expending energy) to replenish their energy stores and be successful in growth and reproduction.

3.11 Marine debris ingestion

The threat of marine debris ingestion has been assigned a relative concern level of 2, or low to moderate relative concern. The extent of this threat is range wide and it is likely intermittent in frequency. Although the sample size is still low, three of the five stranded MHI IFKWs had some form of marine debris in their stomach contents including a plastic bottle, small cable, a small ball of fishing line, and multiple fishing hooks from a number of different fisheries. While not established as the cause of death for these animals, the debris may have impeded their ability to forage and/or compromised their health (Kristi West, Hawai'i Institute of Marine Biology, pers. comm. 2016). This small sample size limits our evaluation of frequency, magnitude, trend, or severity for this threat but provides evidence that it occurs within the MHI IFKW population. As more strandings are recorded and necropsies performed, sample size for stomach content analysis will increase and allow for better characterization of this threat.

Marine litter has become an increasing problem in the oceans, with plastic debris being the most abundant (Derraik 2002). Because they are lightweight and buoyant, plastics can be transported over long distances in the marine environment and have been found in the deep sea floor, along coastlines and in surface waters in densely populated areas, as well as remote regions of the world (Derraik 2002). Exposure to ultraviolet radiation from sunlight can break down these compounds into small pieces, thus making them available for ingestion by marine organisms (Rios et al. 2007). Ingestion of plastics can obstruct the esophagus and the digestive or intestinal tracts, block gastric enzymatic secretions, and cause other effects that could reduce an animal's ability to feed and, ultimately, its overall fitness (Derraik 2002). Other risks linked to plastic debris include entanglement, exposure to environmental contaminants (e.g., PCBs, DDTs) contained in plastic resins, and introduction of alien species (Derraik 2002, Rios et al. 2007).

There are very few large-scale programs to measure total quantity of marine debris in the environment. McDermid and McMullen (2004) offer a quantitative analysis of small plastic debris on beaches in Hawaiʻi, but only 4 of their 20 sample sites were within the range of MHI IFKWs (i.e., most sites were in the Northwestern Hawaiian Islands). In addition, small plastics are only a subset of marine debris in Hawaiʻi and the authors surveyed beach sites, which may or may not be representative of what is out in the marine environment.

Rios et al. (2007) measured a range of PCB, DDT, and polycyclic aromatic hydrocarbon (PAH) levels in plastic particles collected along Hawaiian beaches, and found ∑PCBs and ∑PAHs concentrations ranging from < limits of quantization (< LOQ) to 980 ng/g and < LOQ to 500 ng/g, respectively. Other studies have reported that plastic pellets collected from the coast of Japan contain appreciable levels of PCBs, DDT, and nonylphenol in these granules (Mato et al. 2001, Endo et al. 2005). Thus, ingestion of these particles could cause physiological problems as well as increase the levels of PCBs, DDTs, and other toxic contaminants to which marine biota are exposed.

3.12 Intentional harm (e.g., shooting, poisoning, explosives)

This threat has been assigned a relative concern level of 2, or low to moderate relative concern. Although intentional harm is likely a rare/unknown event, it has an unknown trend and high severity, and any one incident has the potential to result in serious injury or mortality for one or more MHI IFKWs. Given the small population size, serious injury or mortality of even one individual could significantly affect the entire MHI IFKW population.

Fishermen in Hawaiʻi have reported intentionally harming or deterring cetaceans via shooting, explosives, or chemicals to avoid losing catch or bait (Shallenberger 1981, Schlais 1985, Nitta and Henderson 1993, Kobayashi and Kawamoto 1995, Tetra Tech 2009, Baird 2016). Because fishermen have a difficult time differentiating between a false killer whale and some other "blackfish" (e.g., pygmy killer whale, short-finned pilot whale, melon-headed whale) (Madge 2016), it is unknown whether false killer whales have actually been the directed target. Anecdotal information off the north side of Maui indicates that MHI IFKWs may have been affected by deliberate shootings because of interactions with small-scale fisheries (WPRFMC 2009). Harnish et al. (2019) report that shooting cetaceans to prevent or deter depredation is still occurring and report an incident in which a resident common bottlenose dolphin calf in

Hawaiian waters was apparently shot through the melon and survived for at least four months following the shooting.

3.13 Oil spills

The threat of oil spills has been assigned a relative concern level of 1, or low concern. Oil spills thus far have been rare events in the main Hawaiian Islands. In the event of a spill, direct effects would likely be localized to the spill area, with containment and cleanup efforts mounted quickly. According to satellite tracking data, MHI IFKWs travel frequently and quickly and thus have the ability to leave the area to limit or prevent exposure. However, it is unknown if MHI IFKWs would definitively leave the area. For example, Matkin et al. (2008) reported that killer whales did not attempt to avoid oil-sheened waters following the Exxon Valdez oil spill in Alaska. The trend of the frequency of the threat of oil spills negatively affecting MHI IFKWs appears to be stable with a variable severity of this threat.

Oil spills have been reported only a few times in the main Hawaiian Islands. This includes a 1989 spill near Oʻahu when a grounded tanker leaked 117,000 gallons (http://www.nytimes.com/1989/03/04/us/tanker-spills-oil-off-hawaiian-coast.html); a 1996 oil spill in Pearl Harbor after a pipeline broke spilling >25,000 gal. of oil; and a spill at Barbers Point in 2014. The most likely areas for an oil spill in Hawaiʻi are at trans-shipment locations at Barbers Point and along the south shore of Oʻahu. While this area is not a high-density area, it is an important travel corridor as reflected in the high number of visits per area revealed in the analyses undertaken in relation to critical habitat for the MHI IFKW (Baird 2017). The effect of these spills on MHI IFKWs and their prey is unknown but potentially can lead to deleterious health effects if oil is directly inhaled or ingested, or indirectly consumed by affected prey. Additionally, given the social grouping patterns of MHI IFKWs, it is likely that if there was an oil spill an entire social cluster could be exposed.

Oil is made up of thousands of different chemicals, including aliphatic, alicyclic and aromatic compounds (Clark and Brown 1977). Some of the most toxic of these petroleum-related compounds are the volatile PAHs. These compounds are prevalent in coastal waters, especially in urban embayments, and have been shown to alter normal physiological function in marine biota (Varanasi et al. 1989, Stein et al. 1993). Concerns exist over the effects of exposure to PAHs, alone or in combination with other toxic contaminants, on marine mammals because of the worldwide use of fossil fuels (Geraci and Aubin 1990) and the occurrence of oil spills in areas that support marine mammal populations. Marine mammals can be exposed to oil by various routes, such as inhalation of PAHs, direct ingestion of oil, and consumption of contaminated prey (O'Hara and O'Shea 2001). After the *Exxon Valdez* oil spill in Alaska in March 1989, several killer whales were observed to swim through oiled waters in the region and 14 killer whales (33%) from the local AB pod disappeared between 1989 and 1991 (Dahlheim and Matkin 1994). There was no clear evidence to link the oil exposure to the disappearance (and presumable deaths) of these whales, but it is plausible (Matkin et al. 2008).

3.14 Predation (killer whales, tiger sharks, etc.)

The threat of predation overall has been assigned a relative concern level of 1, or low concern. This is because of no documented incidents of predation to MHI IFKWs by killer whales, and the rare event of overlap in time and space between MHI IFKWs and killer whales in Hawaiʻi. However, as for predation by large sharks such as tiger sharks, there are two individual MHI IFKWs in the photo-ID catalog with scars from large shark bites (Robin Baird, Cascadia Research Collective, pers. comm. April 2019; Baird 2019b). This indicates that predatory attacks do happen in Hawaiʻi, although we do not know how often the whale is killed outright. As noted in Baird (2016), there are no photos of live spotted or spinner dolphins with healed large shark bite scars, yet it is known that both species are killed by large sharks at least occasionally. Although the trend appears stable, the severity to MHI IFKWs is considered unknown but potentially high if the predation event results in serious injury or mortality.

In March 2010, the first record of a killer whale predation event on a false killer whale was documented off the coast of New Zealand (Visser et al. 2010). After the attack, killer whales were observed feeding on the carcass of a false killer whale calf. Cascadia Research Collective's photo-ID catalog currently contains 44 individual killer whales sighted in Hawaiian waters, and only one re-sighting. Sightings have occurred in all months of the year except December. Photo-ID and satellite tag data suggest that killer whales in Hawaiian waters are part of a large population that broadly ranges over a wide part of the central tropical Pacific; they are considered rare in Hawaiian waters (www.cascadiaresearch.org). Predation on false killer whales in Hawaiian waters has not been documented.

As mentioned above, predation by sharks has not been directly observed but there are two MHI IFKW individuals in the photo catalog that have evidence of having survived attacks by large sharks (Baird 2016). Tiger sharks (*Galeocerdo cuvier*) are the most likely cause of the injuries observed; however, this has not been confirmed (Robin Baird, Cascadia Research Collective, pers. comm. 2016).

3.15 Incidental take in commercial longline fisheries (i.e., deep-set and shallow-set)

The threat of incidental take in commercial longline fisheries is rated as a relative concern level of 1, or low concern. The spatial extent of this threat is localized since the area of overlap between commercial longline fishing and MHI IFKWs is only 5.4% of its range. The frequency is rare, trend is stable, and the severity is low based on the negligible impact determination of mortality and serious injury in the longline fisheries under MMPA section 101(a)(5)(E).

Commercial longline fishing has been largely excluded from the MHI IFKWs' range since the implementation of the LLEZ in 1992. Following the False Killer Whale Take Reduction Plan's revision to the LLEZ, which removed a seasonal contraction of the LLEZ and prohibited longline fishing within the full LLEZ year-round (see below), and the recent revision to the MHI IFKWs' boundary (Bradford et al. 2015), currently only 5.4% of the MHI IFKW range overlaps with active longline fishing areas (see Figure 2–2 and Figure 2–3).

The commercial deep-set Hawaiʻi longline fishery is designated as a Category I fishery, meaning it experiences frequent incidental mortality and serious injury of marine mammals. This fishery, which has 145 vessels/person per the 2020 Final LOF (85 FR 21079), primarily targets bigeye tuna using deep-set gear in a very broad radius around the Hawaiian Archipelago. Longline fishing gear consists of a mainline strung horizontally across 1–100 km of ocean, supported at regular intervals by vertical float lines connected to surface floats. Descending from the main line are branch lines, each ending in a single, baited hook.

The commercial shallow-set Hawaiʻi longline fishery is designated as a Category II fishery, meaning it experiences occasional incidental mortality and serious injury of marine mammals. This fishery, which has 18 vessels/persons per the 2020 Final LOF (85 FR 21079), primarily targets swordfish using shallow-set gear, fishing mostly in the North Pacific Transition Zone north of Hawaii (Bigelow et al. 1999). More detail on both the longline fishing methods and the history of the fishery can be found in Oleson et al. (2010).

Beginning in 1994, onboard observers in Hawaiʻi-based commercial longline fisheries have systematically recorded information on interactions with protected species, including sea turtles, seabirds, and marine mammals. Observer coverage initially was about 4% for all longline effort combined, but increased beginning in 1999. Since 2004, observer coverage has been 100% for shallow-set (swordfish targeting) trips and 20% for deep-set (tuna targeting) trips based on terms and conditions from an ESA section 7 biological opinion on the fisheries.

False killer whales have been the most frequently hooked or entangled cetacean, primarily during tuna-targeting longline sets (Forney and Kobayashi 2007, McCracken and Forney 2010). When the population identity of a false killer whale that has been hooked or entangled by the longline fisheries within the MHI IFKW/pelagic overlap zone (see Figure 2–2 and Figure 2–3) cannot be determined without genetic samples or photographs that could be matched to the Cascadia photo-ID catalog, NOAA Fisheries prorates the interaction to either the pelagic or MHI insular population based on population densities, as described further below.

The mortality and serious injury (M&SI) for false killer whales bycaught in Hawaiʻi-based commercial longline fisheries exceeded potential biological removal (PBR) as defined for this species under the MMPA. As a result, in January 2010, a False Killer Whale Take Reduction Team (FKWTRT) was formed and charged with drafting a False Killer Whale Take Reduction Plan (FKWTRP) to reduce M&SI of the species. For the 5-year period (2008–2012) prior to the implementation of the FKWTRP (discussed in greater detail in section 4.3), the average estimated M&SI for the MHI IFKW population was 0.21 animals per year, which exceeded the PBR of 0.18 or ~one animal every 5.5 years. Following implementation of the FKWTRP, a significant portion of the MHI IFKWs' range is inside of the expanded year-round LLEZ around the main Hawaiian Islands, providing significant protection from longline fishing. Prior to that time, a seasonal contraction to the LLEZ potentially exposed a significant portion of the offshore range of the MHI IFKW to longline fishing. Because of the significant change in longline fishery activity relative to the MHI IFKW under the FKWTRP, the status of the population is assessed relative to the post-FKWTRP period (2013–2015). For this period the estimate of M&SI injury (0.01) is below the PBR (0.30). However, the total fishery M&SI for the MHI IFKW cannot be considered to be insignificant and approaching zero, as it is greater than 10% of PBR (Carretta et al. 2018).

There are a variety of variables that may have played into the change in M&SI, including a change in the method for prorating blackfish interactions and assigning them to different populations, as described in more detail below. It is too early to determine if the FKWTRP measures are responsible for this reduction or if other factors have also contributed (e.g., new proration method, unrelated changes in fishing locations/effort, expansion of the Papahānaumokuākea Marine National Monument causing geographic shifts in fishing effort, etc.). Measures in the FKWTRP include gear modifications and guidance for responses by captains and crew members to de-hook or disentangle animals. Longline fisheries are observed for protected species interactions and rigorous data are collected for each documented interaction. Whenever possible, observers collect photos, video, and/or biological samples from the animal so we can determine to which population it belongs. But more often, an individual recorded as bycatch is prorated based on the location of the interaction, as described in the final 2017 SAR (Carretta et al. 2018):

> "Annual bycatch estimates are prorated to stock using the following process. Takes of unidentified blackfish are prorated to false killer whale and short-finned pilot whale based on distance from shore (McCracken 2010). The distance-from-shore model was chosen following consultation with the Pacific Scientific Review Group, based on the model's logic and performance relative to a number of other models with similar output (McCracken 2010). Following proration of unidentified blackfish takes to species, Hawaiʻi EEZ and high-seas estimates of false killer whale take are calculated by summing the annual false killer whale take and the annual blackfish take prorated as false killer whale within each region (McCracken 2017). For the deep-set fishery within the Hawaiʻi EEZ, annual takes are apportioned to each stock overlap zone and the pelagic-only stock area based on relative annual fishing effort in each zone. The total annual EEZ bycatch estimate is multiplied by the proportion of total fishing effort (by set) within each zone to estimate the bycatch within that zone. Because the shallow-set longline fishery is fully observed, takes are assigned to the zone in which they were observed and there is no further apportionment based on fishing effort. For each longline fishery, the zonal bycatch estimates are then multiplied by the relative density of each stock in the respective zone to prorate bycatch to stock. For the deep-set fishery, if bycatch was observed within a specific overlap zone, the observed takes were assigned to that zone and the remaining estimated bycatch was assigned among zones and stocks according to the described process. Following proration by fishing effort and stock density within each zone, stock-specific bycatch estimates are summed across zones to yield the total stock-specific annual bycatch by fishery. Uncertainty in stock-specific bycatch estimates combines variances of total annual false killer whale bycatch and the fractional variance of false killer whale density according to which stock is being estimated. Enumeration of fishing effort within stock overlap zones is assumed to be known without error."

3.16 Interactions with aquaculture facilities and other marine structures

The threat of interactions with aquaculture facilities or other marine structures is rated as a relative concern level of 1, or low concern. The extent of this threat is localized in areas that contain marine structures, the frequency of this threat occurring is rare, the trend is currently stable but with the potential to increase in the future as more aquaculture facilities and other marine structures are permitted and constructed, and the severity to the DPS is low. As with other threats, this threat will continue to be monitored due to potential increase in the number of permitted facilities and structures, as discussed below.

In 1978, the State of Hawaiʻi developed the first formal aquaculture development plan in the United States. In 1993, the state updated the aquaculture plan and transferred responsibilities for aquaculture development from the Hawaiʻi Department of Land and Natural Resources to the Hawaiʻi Department of Agriculture. In 1999, the Hawaiʻi legislature approved ocean leasing for aquaculture (Buttner and Karr 2009). Furthermore, the Western Pacific Regional Fishery Management Council recommended that NOAA Fisheries establish an aquaculture permit for federal waters (3–200 miles from shore) of the Pacific Islands Region. As such, NOAA Fisheries is developing an aquaculture management program to regulate where, how, and how much aquaculture may occur, and provide clear guidance to the industry. Through a programmatic environmental impact statement, NOAA Fisheries Pacific Islands Regional Office (PIRO) is analyzing potential environmental, social, and economic effects associated with the aquaculture management program (81 FR 57567; August 23, 2016). This program will support offshore aquaculture development by identifying appropriate management unit species for aquaculture, reasonably foreseeable types of offshore aquaculture operations, and permitting and reporting requirements for conducting aquaculture activities in federal waters.

Currently, the Pacific Islands region produces a wide variety of crustaceans, finfish, mollusks, and algae for consumption, with most of the production in Hawaiʻi (U.S. Department of Agriculture 2015). In Hawaiʻi, there are permitted net pen facilities in both state and federal waters to culture finfish, including Blue Ocean Mariculture, a commercial open ocean mariculture farm in state waters off Keahole Point (Hawaiʻi Island) that raises juvenile kampachi (*Seriola rivoliana*) fish from larvae before being transferred to offshore open ocean net pens on the leeward side of the island.

In 2003, Blue Ocean Mariculture received a State of Hawaii Division of Land and Natural Resources (DLNR) Conservation District Use Permit and ocean lease for the operation of 6 submersible net pens, anchored across 90 acres, and located ~2,000 feet offshore in a water depth of 200–220 ft. Based on public comment, including input from the Hawaiian Islands Humpback Whale National Marine Sanctuary (Sanctuary), Blue Ocean Mariculture made modifications from their original proposal in order to move the net pens as far offshore as possible so that it would reduce the chance of funneling whale movements past the pens and to no longer overlap with spinner dolphin resting habitat. Blue Ocean Mariculture is only permitted to culture a variety of local Hawaiian species; they currently only produce Hawaiian kampachi. When submerged, the net pens are 30 ft beneath the surface. The total capacity (area) of the net pens was not to exceed 15,300 m^3 (2,600 m^3 per pen). The net pens are anchored in the soft substrate using anchors and concrete block weights, with a series of buoys and weights to ensure anchor lines are perpetually taut. Per input from the Sanctuary, the number of lines is kept to a minimum, lines are made as visible as possible without the use of streamers or attachments, and no acoustic deterrents are used. In 2009, Blue Ocean Mariculture received approval to modify their permit by decreasing the number of nets to five but increasing the capacity of the pens to 7,000 m^3 or less. In 2014, Blue Ocean Mariculture received approval to expand the allowable capacity to 72,000 m^3 by increasing the number of nets to 8 and increasing maximum allowable size of pens to 8,000 m^3. To date there have been no entanglements of marine mammals at the facility. There was a reported instance of an employee feeding dolphins. This employee was terminated and all employees must now sign forms promising to abide by both permit and federal regulations (Blue Ocean Mariculture 2014).

In July 2016, NOAA Fisheries issued a Special Coral Reef Ecosystem Fishing Permit to Kampachi Farms, LLC for the culture and harvest of *S. rivoliana* using a net pen system. This net pen was tethered to an existing mooring located in federal waters approximately 5.5 nm offshore west of Keauhou Bay on the Island of Hawaiʻi. This permit authorized the culture and harvest of a maximum amount of 30,000 kampachi fish or approximately 120,000 lbs. In December 2016, the mooring system failed prior to any fish being stocked in the recently deployed net pens. Although the operators tried to retrieve all of the equipment and return it to shore, strong currents and poor weather conditions made recovery of both the platform buoy and net pen impossible. Accordingly, the operators scuttled the net pen approximately 15 miles southwest of the Island of Hawaiʻi in approximately 12,000 feet of water. The net pen sank immediately, and the remainder of the system (platform buoy and sensitive electronic monitoring gear) was successfully returned to Kawaihae Harbor. The permit contained an Emergency Reporting Plan, which included the immediate notification of NOAA Fisheries, Army Corps of Engineers, and U.S. Coast Guard. These agencies provided response and recovery guidance to minimize human safety and environmental concerns. There were no interactions with protected species (sea birds, marine mammals, or sea turtles), and there was no release of hazardous or toxic material. In 2017, the permit to continue harvest of kampachi fish was transferred to Forever Oceans.

A federal permit was also issued to Hawaiʻi Ocean Technology, Inc. to culture bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*T. albacares*) in large sphere-shaped untethered fish cages off Kawaihae on the west side of Hawaiʻi Island. Twelve “oceansphere” cages were expected to produce 6,000 tons of tuna per year. Oceanspheres, with a diameter of 177 ft, were designed to dangle anchorless about 65 ft below the surface and about 1,250 ft above the ocean floor using a combination of ballast, thruster control, and surface buoys. However, in December 2016, Hawaiʻi Oceanic Technology, Inc. dissolved itself and these mariculture efforts were abandoned.

There are several types of potential effects to MHI IFKWs from aquaculture gear and operations. These include entanglement in gear including mooring lines, bridles, and netting; collisions with vessels including propellers; effects of noise and disturbance; effects of wastes or spills; effects of fishing by others around an array; and effects to behaviors, including food conditioning and habituation to activities associated with the facility.

Price et al. (2017) provide a thorough review of protected species interactions with marine aquaculture facilities. The authors note that the research and data analyzed for their assessment:

> "…indicate interactions and entanglements with aquaculture gear worldwide are rare and close approaches by protected species are seldom documented. It is unclear, though, if this is because farms are relatively benign and pose little risk, or because the number and density of farms is so low that the detection level for harmful interactions is also small. There remains an overall general lack of scientific reporting on aquaculture-related entanglement frequency and severity of resulting injuries, mortality rates associated with interactions, effective deterrent methods, and technological innovation to reduce interactions and decrease harm if contact occurs. Importantly, negative data—scientifically collected data reflecting the lack of interactions with protected species—is also lacking. This makes it difficult to know if the paucity of reported incidents is due to low numbers of interactions or failure to detect and report them."

The majority of the information available and analyzed for this review is about shellfish aquaculture, which often uses gear with a lot of lines and other entanglement hazards. Other negative effects of aquaculture facilities identified for protected species include habitat exclusion or modification leading to less use or less productive use, and underwater noise disturbance. The authors compiled a table of all global cases of protected species interactions with aquaculture gear, including 16 cetacean species interacting with a variety of gear types, but primarily entanglement in shellfish aquaculture facilities (see Table 8 in Price et al. 2017). Of note is that there are currently no offshore shellfish operations in Hawaii and there have been no requests to conduct these types of operations to date (Kate Taylor, NOAA PIRO, pers. comm. August 2019).

Marine mammal interactions with marine finfish aquaculture, which is more applicable to the type of aquaculture likely to be developed in Hawaiʻi within the range of MHI IFKWs, was reviewed and summarized by Price and Morris (2013). Marine aquaculture operations may displace marine mammals from their foraging habitats (Markowitz et al. 2004, Cañadas and Hammond 2008) or cause other disruptions to their behavior (Early 2001). Entanglement in nets or lines around fish farms may cause injury, stress, or death to marine mammals. Kemper et al. (2003) evaluated negative interactions of marine mammals with aquaculture in the southern hemisphere and found that most known interactions occur at finfish farms (versus shellfish farms) and involve predatory pinnipeds (versus cetaceans). Currently, there are no published data on interactions of false killer whales with finfish aquaculture in Hawaiʻi. However, Baird (2016) notes bottlenose dolphins being deliberately fed by workers at a finfish aquaculture farm off Kona, Hawaiʻi (see above) as well as dolphins feeding on escaped fish, which has led to habituation. As such, the most reliable place on the Kona coast to find bottlenose dolphins is around the net pens currently in place. This type of interaction has the potential to cause changes in MHI IFKW movement patterns and increase the likelihood of habituation to humans. Overall, review of the U.S. Atlantic and Gulf of Mexico marine mammal stock assessment (Waring et al. 2012, 2015 as discussed in Price et al. 2017) finds very few verified instances of marine mammals being injured by or entangled in aquaculture gear.

NOAA Fisheries PIRO continues to conduct ESA section 7 consultations on aquaculture activities in the region that are federally authorized, funded, or carried out, to ensure they do not jeopardize the existence of an endangered or threatened species. Until March of 2017, ocean aquaculture facilities located in state waters and moored offshore of the Island of Hawaiʻi had not reported any incidents of protected species entanglements in a combined 15 years of operation (Hukilau Foods 2009, Kona Blue Water Farms 2009). However, on March 5, 2017, an adult male Hawaiian monk seal was discovered dead inside a net pen that was in the process of being decommissioned. During this decommissioning, a 40 ft x 40 ft panel was removed from the net pen to allow the escape of a blacktip reef shark (*Carcharhinus melanopterus*) that had entered through a small forced hole. No fish were being cultured in the net pen at the time. When the crew returned the next day to continue decommissioning, the shark was gone but they discovered a monk seal on the floor of the cage. Apparently, the seal drowned as a result of its inability to exit through the 1,600 sq ft opening and reach the surface. This is the first such incident with a protected species in Hawaiʻi. As a result, an ESA section 7 consultation was reinitiated and the operation has modified its protocols to prevent such incidents in the future. Additionally, all permitted mariculture facilities in Hawaiʻi now use best management practices to reduce interactions or entanglements with marine mammals. These include: daily inspection of the net pens for openings and immediate repair when needed, the use of predator-resistant netting materials where possible, the maintenance of a 15-ft air gap for any net pen that has an underwater opening, conducting install/removal operations when the area is free of ESA-listed species, not leaving a partially assembled cage unattended in a submerged position, removal of top netting first when disassembling a cage for decommissioning, and initiation of the "Unwanted Animal Procedure" if an unwanted animal has entered the cage.

There is potential for additional aquaculture facilities to be developed within the range of MHI IFKWs in the future. NOAA Fisheries has a marine aquaculture strategic plan for 2016–2020 that establishes a target of expanding sustainable U.S. marine aquaculture production by at least 50% by the year 2020 (NOAA Fisheries 2015). It remains to be seen how this national goal will be implemented in the Pacific Islands Region, specifically in Hawaiʻi.

Development of other marine structures, such as alternative energy arrays (e.g., wave, wind, and solar), is expected to increase in Hawaiʻi. For example, in June of 2015, a wave energy device known as *Azura* was deployed at the U.S. Navy's Wave Energy Test Site near Kāneʻohe Bay, Oʻahu, Hawaiʻi (http://azurawave.com/northwest-energy-innovations-launches-wave-energy-device-in-hawaii/). This test device, which stands 12 ft above the surface and extends 50 ft below, converts the waves' vertical and horizontal movements into up to 18 kilowatts of electricity. Another test device in the area is a 50-ft-wide, doughnut-shaped device called the *Lifesaver*. This 3-ft-tall ring is anchored to the ocean floor with cables; when the buoy is moved by the sea, the cables move and turn the wheels of a generator to produce electricity. Currently these are all experimental devices that are operational for short periods of time to test feasibility and the Navy expects to rotate devices in these areas. Ultimately, developers envision dozens of machines that are anchored within a mile or two off the North Shore of Oʻahu (http://www.cbsnews.com/news/wave-powered-electricity-makes-us-debut-hawaii/). To date, no interactions with protected species, including MHI IFKWs, from these devices have been reported, but they may present an entanglement risk.

In 2011, the State of Hawaiʻi requested that the Bureau of Ocean Energy Management (BOEM) form a BOEM-Hawaiʻi intergovernmental renewable energy task force, which provides for coordination and consultation on renewable energy projects that may affect Hawaiʻi (BOEM-Hawaiʻi 2017). BOEM has since received three unsolicited lease requests for floating wind energy projects offshore of Oʻahu and has published a "Call for Information and Nominations for Commercial Leasing to Wind Power on the Outer Continental Shelf, Offshore of Oʻahu," (81 FR 41335; June 24, 2016). This announcement begins a long-term evaluation and planning process for any potential projects off Oʻahu. Floating wind energy projects would include anchoring platforms with wind turbines offshore and transferring energy via undersea cables to shore (BOEM-Hawaiʻi 2017). These structures may act as fish aggregating devices attracting prey species and potentially deterring some fishing due to the extended field of structures (Leeney et al. 2014). Given the large size of this as a potential attractant, it is difficult to determine how this may affect whale behavior in and around these areas and additional monitoring may be necessary to understand how prey and whale habitat use may be affected. Other effects like associated noise and water quality changes are expected to be minimal (NOAA Fisheries 2017c). The development of any such projects would be subject to thorough review under ESA section 7 consultation.

Risk to cetaceans and other protected species can be minimized by siting aquaculture farms and alternative energy arrays in areas away from known "hot spot" areas and known migration routes, using rigid net materials or secondary rigid anti-predator nets, and keeping mooring lines taut. As previously mentioned, any new developments requiring federal permits or funding would be subject to consultation under section 7 of the ESA. Section 7 biologists should consider the best scientific and commercial data available on distribution of MHI IFKWs' critical habitat and "hot spots" that have been identified as high use areas when evaluating in-water construction projects under section 7.

3.17 Vessel strikes

The threat of vessel strikes has been assigned a relative concern level of 1, or low concern. Vessel strikes may occur range wide, but the risk likely would be concentrated in areas of high vessel traffic. Based on the available observations, it is a rare event, with only one potential vessel strike injury to a MHI IFKW recorded thus far. The severity of this threat is considered low, with a trend that is stable to increasing. The concern of this threat could be reevaluated in the event of significant changes in vessel traffic within the MHI IFKWs' range or evidence of vessel strikes appearing in the form of injuries or scars in surveyed individuals. As noted previously, the HTA's 5-year Strategic Plan calls for continued growth of Hawaiʻi's visitor industry (HTA 2016), which may lead to increased vessel traffic for leisure activities.

Although more commonly observed in large whales, vessel strikes have the potential to kill or injure smaller cetaceans including false killer whales. Propeller strikes from large vessels are likely to be fatal, while propeller injuries from small boats may cause disfigurement of the dorsal fin or other parts of the body without killing the whale outright (Wells et al. 2008). Slow-moving animals, or animals that associate with vessels, (i.e., to ride the bow waves of a vessel or depredate catch on fishing gear) are likely the most susceptible to vessel strikes. At least one juvenile killer whale that frequently approached vessels was killed by an injury caused by a vessel off British Columbia, Canada (Laist et al. 2001, Gaydos and Raverty 2007). False killer whales in waters surrounding Hawaiʻi (belonging to both insular and pelagic populations) are known to ride the bow or stern wake of vessels and may come into proximity of propellers (Robin Baird, Cascadia Research Collective, pers. comm. 2010). No vessel-strike related injuries or deaths of false killer whales have been documented in Hawaiian waters, but Baird (2009) reported a fresh head wound on one MHI IFKW individual photographed off Oʻahu in September 2009 that may have been caused by a propeller strike.

3.18 Whale/dolphin watching and other ecotours

The threat of whale/dolphin watching and other ecotours has been assigned a relative concern level of 1, or low concern. It is likely to be localized as ecotour operations tend to be concentrated in certain areas as mentioned below. Although some dolphin watching tours do occur year-round, it most likely poses an intermittent threat that may be more concentrated seasonally when whale watching is also occurring. This threat is assigned to the lowest concern level since there is not yet evidence of negative effects from this threat to MHI IFKWs, such as in-water interactions (i.e., swimming with, harassing) or the indirect effects of increased vessel noise and disturbance, but there is potential for it to occur, especially if whale and dolphin watching increases in the future. Severity of the threat to MHI IFKWs is considered low and the trend is stable. As noted previously, the HTA's 5-year Strategic Plan calls for continued growth of Hawaiʻi's visitor industry (HTA 2016), which may lead to increased whale and dolphin ecotourism activities.

Whale watching operations are common in Hawaiʻi during the winter and spring humpback whale breeding season. Most whale watching operators depart and return from the west shore of Maui, however, some operators use ports along the Kona coast of Hawaiʻi Island and the west coast of Oʻahu. Although none of these operations target their activities on false killer whales, most will stop to watch them when they are encountered. Similarly, dolphin ecotours are common on Hawaiʻi Island, Maui, and Oʻahu and work year-round. There have been reports of dolphin ecotours allowing customers to enter the water with spinner dolphins, pilot whales, and other cetaceans, including false killer whales.

Like humpback whale tourism, spinner dolphin tours do not target false killer whales but some are known to take customers to offshore waters in search of species other than spinner dolphins. There have been no reported interactions or infractions of whale or dolphin watching activities with false killer whales and the level of risk to MHI IFKWs is unknown.

3.19 Competition with marine species (marlins, sharks, etc.)

The threat of competition with marlins, sharks, and other top predators has been assigned a relative concern level of 1, or low concern. Better knowledge of prey preferences and predator-prey dynamics is needed to fully understand the potential effects to MHI IFKWs from natural competition. The extent of this threat is range wide, with continuous frequency, unknown trend, and low severity.

As described above in more detail in section 3.4, reduced prey size and reduced total prey biomass are factors presumably affecting MHI IFKWs. In addition to competition with fisheries as noted in several sections above, another potential contributing factor towards changes in prey quality and availability may be competition with other large marine predators. Large pelagic and coastal sharks might be important competitors to MHI IFKWs, and changes in the abundance of these sharks may affect the level of competition with MHI IFKWs, although the level of competition is unknown. Stock assessments for sharks are limited, but biomass of large sharks is likely much reduced from its pristine condition. Shark finning was banned in Hawaiʻi in 2000, but prior to this ban, shark finning may have affected shark populations within the MHI IFKWs' range. Clarke et al. (2012) report that there is little evidence of a reduction of finning in longline fisheries in the western and central Pacific Ocean; however, this study may not be informative of what is occurring in Hawaiʻi as most longlining is occurring outside the range of MHI IFKWs. In addition, the authors note that several shark species are more often retained than finned, which suggests more than a finning prohibition is required to reduce mortality rates from fishing and allow shark populations to rebound. Additionally, movement of other large predatory species' ranges is likely to change because of climate change, which could affect competition with MHI IFKWs. This threat is another factor that may possibly contribute to reduced prey size and total prey biomass as described above.

3.20 Live capture for aquaria (historic threat)

Live capture of false killer whales occurred prior to 1990 but has been eliminated and has not occurred for nearly four decades. This threat, while no longer a current or future threat to MHI IFKWs, may have contributed to historic declines.

4 CONSERVATION MEASURES

Current conservation measures in place for MHI IFKWs can be grouped into four categories, each of which is discussed further below: (1) protections afforded through the ESA, including the State of Hawaiʻi's ESA section 6 Cooperative Agreement, section 7 consultations, section 9 take prohibitions, and section 10 permits and habitat conservation plans; (2) protections afforded through the MMPA, including take prohibitions, the authorization of incidental take under the MMPA, and the False Killer Whale Take Reduction Plan; (3) active research programs to fill data gaps; and (4) outreach and education, including marine wildlife viewing guidelines.

In addition to these four categories, there are several international protections in place for false killer whales in general that are worth mentioning, even as we recognize that MHI IFKWs do not occur outside of U.S. waters. In 2003, false killer whales as a global species were listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), although MHI IFKWs are not currently traded. The International Whaling Commission (IWC) is an inter-governmental organization of which the United States has been an active member since its establishment in 1948. In 1982, the IWC adopted a moratorium on commercial whaling, which is also illegal under the MMPA. The IWC encourages, coordinates, and funds whale research, and publishes the results of scientific research. And finally, in July of 2018, the International Union for Conservation of Nature (IUCN) Red List, which assesses the risk of extinction to a species, classified false killer whales globally as Near Threatened (Baird 2018a) (this is a revision to the 2008 classification of Data Deficient). Justification for the change in global designation to Near Threatened is as follows: 1) the estimated population decline of >50% in two generations in the one population (MHI IFKW) that has been quantitatively assessed, with the primary cause thought to be fishery interactions; 2) bycatch is a widespread threat at levels suspected to be large enough to result in population reduction throughout much of the taxon's range, and levels of fishing effort are unlikely to decline substantially in the near future; 3) levels of directed take in some areas are likely high enough to have reduced local populations; and 4) biological susceptibility to population-level effects of bycatch exists given the life history of these whales, the overlap of their diet with the target species of high-value commercial fisheries, and their tendency to engage in depredation on catch and bait in hook-and-line fisheries (Baird 2018c). Although the IUCN Red List assessment is for the global species, the Near Threatened classification can help draw attention to this species and provide information to guide actions to conserve the species.

4.1 ESA Protections

ESA Section 6

Section 6 of the ESA provides a mechanism for cooperation between NOAA Fisheries and states in the conservation of threatened, endangered, and candidate species. In 2006, NOAA Fisheries entered into a cooperative agreement with the State of Hawaiʻi to establish and maintain an "adequate and active" program for the conservation of endangered and threatened species. Through this agreement, which is renewed annually, NOAA Fisheries is authorized to assist in, and provide federal funding for, implementation of a state's conservation program. Federal funding, provided in the form of grants, can be used to support management, research, monitoring, and outreach projects that have direct conservation benefits for listed species, recently delisted species, and candidate species that reside within that state.

Hawai‘i's section 6 cooperative agreement is through the Hawai‘i DLNR and is conducted under the auspices of the DLNR's Marine Wildlife Program within the Division of Aquatic Resources (DAR). This cooperative agreement is geared toward conservation of five endangered species, including the MHI IFKW, and one threatened species.

In 2015, DLNR–DAR was awarded a multi-year grant totaling over $1.5 million dollars (federal and non-federal funding) over three years. The grant focused primarily on conservation and long-term management of MHI IFKWs and included the following objectives: fill in data gaps in the spatial use patterns of MHI IFKWs including both temporal (seasonal and inter-annual) and group-specific spatial use patterns; assess fisheries-related injuries to determine the percent of false killer whales that are likely interacting with fisheries; obtain photo-ID data to contribute to mark-recapture abundance estimates; obtain biopsy samples for examination of reproductive and stress hormone levels as well as trends in POPs; assess the spatial and temporal overlap between MHI IFKWs and state fisheries effort; identify and evaluate threats by conducting stranding investigations that include screening for infectious diseases and examination of anthropogenic effects; and target outreach and awareness to specific fishermen, boaters, and tour operators to effectively mitigate or reduce interactions with false killer whales (State of Hawai‘i DLNR 2019). Substantial administrative and hiring delays extended the original duration of the 2015 multi-year grant into 2019, but nonetheless, efforts have advanced the section 6 grant objectives to lay important ground work for the conservation and management of MHI IFKWs.

In August 2019, a new multi-year grant totaling over $1.5 million dollars was awarded to the State of Hawai‘i's DLNR–DAR. Objectives specific to MHI IFKWs include: assessing the health of MHI IFKWs via collection and analysis of biological samples from live individuals during field work and during stranding investigations; addressing gaps in spatial data, including temporal (seasonal and inter-annual) and group-specific patterns; modifying DAR's online CML monthly catch report to add a mandatory sighting report of protected species to the form; and conducting targeted outreach to fishers, boaters, and tour operators to reduce and mitigate interactions, improve identification of species for greater accuracy in reporting, and increase photo submission and public reporting of strandings.

Cooperation with DLNR–DAR's Marine Wildlife Program to protect and recover MHI IFKWs also includes attending diverse community events such as fishing tournaments. Marine Wildlife Program staff make connections and develop relationships with many of the fishermen who spend time out on the water on a regular basis, potentially sighting and/or interacting with false killer whales. Staff also host outreach tables with messages and giveaways focused on false killer whales. For example, tables focus on the importance of using barbless hooks to reduce interactions with protected species, and include barbless hook samples, false killer whale identification cards for adults, and kits for children that include false killer whale pamphlets, stickers, and temporary tattoos. These outreach events also present opportunities to increase immediate reporting of stranding events by the public by distributing tri-fold cards, and by increasing capacity building for whale response and necropsy on Hawaiʻi Island where five individual MHI IFKW strandings have occurred between 2010 and 2016 (State of Hawaiʻi DLNR 2019).

ESA Section 7

Section 7(a)(1) of the ESA charges federal agencies to aid in the conservation of endangered and threatened species. Discretionary agency activities may include habitat protection, modification, or improvement; survey work to improve the understanding of a species' biology or ecology; assistance in implementing recovery actions from a recovery plan; developing a conservation program for listed species; assistance with providing federal support during a stranding event; etc. While this requirement exists for federal agencies, we are unaware of any current efforts being undertaken by any agency under ESA section 7(a)(1) that benefit MHI IFKWs.

Section 7(a)(2) of the ESA requires federal agencies, through consultation with NOAA Fisheries or the U.S. Fish and Wildlife Service, to ensure that their activities are not likely to jeopardize the continued existence of listed species or adversely modify designated critical habitat. As part of these consultations, NOAA Fisheries may specify reasonable and prudent measures, as well as terms and conditions to implement those measures necessary to minimize effects to listed species from a proposed action by a federal agency. Examples of reasonable and prudent measures recently specified in ESA section 7 biological opinions that pertain to MHI IFKWs include, but are not limited to, the following: collect data on the capture, injury, and mortality caused by Hawaiʻi-based commercial longline fisheries; collect basic life-history information, as available; and require all Hawaiʻi commercial longline vessels to comply with all gear requirements and handling protocols for marine mammals implemented through the FKWTRP (NOAA Fisheries 2014).

ESA Section 9

When the MHI IFKW was listed as an endangered DPS under the ESA in November 2012, all of the take prohibitions of section 9(a)(1) of the ESA were applied (77 FR 70915; November 28, 2012). These include prohibitions against the import, export, use in foreign commerce, or "take" of the species. "Take" is defined under the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct" (16 U.S.C. 1532(19)). These prohibitions apply to all persons subject to the jurisdiction of the United States, including in the United States EEZ or on the high seas.

ESA Section 10

Section 10 of the ESA is designed to regulate a wide range of activities affecting listed species and the habitats upon which they depend. With some exceptions, the ESA prohibits activities affecting protected species and their habitats unless authorized by a permit (i.e., an incidental take permit) from NOAA Fisheries or the U.S. Fish and Wildlife Services. Permitted activities are designed to be consistent with the conservation of the species.

Individuals planning to conduct any activity resulting in the "take" of an endangered or threatened species, deliberate or not, must possess a permit to perform that activity. There are two types of permits under section 10 of the ESA that are applicable to MHI IFKWs. The first type of permit under section 10(a)(1)(A) is for scientific research. An example of this type of permit is for the continuation of a long-term assessment of the biology and ecology of MHI IFKWs. The purpose of this research, issued to Dr. Robin Baird of Cascadia Research Collective, is to obtain information relevant to the management and conservation of the DPS and assess responses to anthropogenic activities. Questions being addressed include the size of the population, habitat use, population structure, social organization, range, movement patterns, movement rates, diving behavior, diet, ecology, disease monitoring, and behavior (NOAA Fisheries 2017b). The second type of permit is for taking species incidental to (not the purpose of) an otherwise lawful activity (section 10(a)(1)(B). This type of permit must be accompanied by a Habitat Conservation Plan. To date, this type of section 10 permit has not been issued for incidental take of MHI IFKWs.

4.2 MMPA Protections

Under the MMPA, take of all marine mammals is prohibited, with certain exceptions. Exceptions can be made through permitting actions for take incidental to commercial fishing and other non-fishing activities; for scientific research; and for public display at licensed institutions such as aquaria and science centers. The MMPA was established to prevent marine mammal species and population stocks from declining beyond the point at which they cease to be significant functioning elements of the ecosystems of which they are a part. A population stock is defined under the MMPA as "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement that interbreed when mature." Because the MHI IFKW is formally listed as "endangered" under the ESA, it is automatically considered a "depleted" and "strategic" stock under the MMPA.

The MMPA also established the concept of "optimum sustainable populations" to ensure healthy ecosystems (versus the more common "maximum sustainable yield" approach used in most marine resource management). For most marine mammals, potential biological removal or PBR is also calculated, which is the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while still allowing that stock to reach or maintain its optimum sustainable population. A strategic stock is a stock for which total human-caused M&SI exceeds PBR, that is declining and likely to be listed as a threatened species under the ESA within the foreseeable future, or that is listed as a threatened or endangered species under the ESA. A take reduction plan must be developed for strategic stocks incidentally taken in Category I or II fisheries, as defined on the annual LOF. The MHI IFKW, first recognized as a stock under the MMPA in the 2008 SAR (Carretta et al. 2009), currently has an established PBR of 0.3 MHI IFKWs per year (Carretta et al. 2018). This means approximately one MHI IFKW every 3.3 years can be removed by unintentional means without being detrimental to the population stock reaching or obtaining its optimum sustainable population level.

False Killer Whale Take Reduction Plan

A Take Reduction Plan (TRP) is a plan to reduce incidental M&SI of strategic marine mammal populations that interact with Category I and II commercial fisheries to specified levels. The FKWTRP was developed under the statutory requirement of the MMPA for both pelagic and

MHI IFKWs because the M&SI for both populations of false killer whales bycaught in Category I and II Hawaiʻi-based commercial longline fisheries exceeded the PBR levels. As a result, in January 2010, a FKWTRT was formed and charged with drafting a plan to reduce M&SI of pelagic and MHI IFKWs. In July 2010, the FKWTRT submitted a consensus Draft FKWTRP to NOAA Fisheries. These recommendations formed the basis of NOAA Fisheries' FKWTRP. In November 2012, NOAA Fisheries published a final rule to implement the FKWTRP (77 FR 71259; November 29, 2012). The plan became effective in 2013, shortly after the DPS was listed in 2012.

The FKWTRP includes measures to reduce false killer whale bycatch in the Hawaiʻi-based deep-set and shallow-set commercial longline fisheries. The FKWTRP also includes research recommendations specific to Hawaiʻi's nearshore hook-and-line fisheries, though these fisheries are not regulated under the TRP. The scope of the FKWTRP may be expanded in the future to include other fisheries as required under the MMPA if information shows other fisheries have unsustainably high levels of false killer whale takes.

The FKWTRP contains eight regulatory incidental take reduction measures (i.e., two gear requirements, two longline management areas, and four measures to improve captain and crew response to hooked or entangled marine mammals) and six non-regulatory measures (i.e., measures that NOAA Fisheries will implement, but which are not required by regulation). In addition, the FKWTRP includes prioritized research recommendations to better inform long-term solutions to reduce false killer whale bycatch.

For the gear requirements, the FKWTRP requires that on commercial deep-set longline trips, only certain hook types can be used. Specifically, hooks must be circle hooks with the wire diameter of 4.5 millimeters (mm) or smaller, and a 10-degree offset or less. To facilitate enforcement of the wire diameter requirement, the FKWTRP requires that the hook shank must contain round (non-flattened) wire that can be measured with a caliper or similar gauge. The hook requirement is intended to reduce the severity of injuries following an interaction. These circle hooks are generally weaker than larger diameter hooks, which may allow the hook to bend or straighten, releasing the animal with no gear remaining attached. The FKWTRP also specifies a minimum diameter (2.0 mm) for monofilament branch lines with a breaking strength of approximately 400 lbs (181 kg), which was expected to reduce the likelihood that the line would break under the strain of a hooked or entangled marine mammal. The intent of this measure, when coupled with the measure limiting the hook diameter, is that the hook will serve as the weakest point of the assembled gear. Consequently, during a marine mammal hooking or entanglement, fishermen could place tension on the line to allow the animal to straighten the hook without breaking the branch line, or fishermen could bring the animal close to the vessel for disentanglement or de-hooking attempts without breaking the branch line. This reduces the chance that the animal will break the line and swim off, still hooked, with substantial trailing gear still attached, which may later cause serious injuries to the animal. The FKWTRP specifies that if any line material other than monofilament is used, it must have a comparable minimum breaking strength (400 lbs).

The two longline management areas are the main Hawaiian Islands longline fishing prohibited area and a "Southern Exclusion Zone" (SEZ) south of the main Hawaiian Islands (Figure 4–1). For the first management area, the FKWTRP establishes a year-round longline fishing prohibited area (or longline exclusion zone, LLEZ) around the entire main Hawaiian Islands. The exclusion zone was created in 1992 (57 FR 7661; March 2, 1992) and allowed the longline fishery to operate seasonally between October and January within a portion of the exclusion zone. The FKWTRP established the entire exclusion zone as a year-round exclusion zone. This is particularly important for MHI IFKWs since it encompasses a vast majority (94.6%) of their range (see Figure 2–3 and Figure 2–4), and leaves only a small portion (5.4%) of the MHI IFKWs' revised range exposed to commercial longline fishing. The second management area established by the FKWTRP is the SEZ south of the main Hawaiian Islands (Figure 4–1). The area will remain open unless the deep-set longline fishery reaches a specific level of M&SI within the EEZ surrounding the Hawaiian Islands. The area would then be closed to longline deep-set fishing as a consequence of exceeding sustainable levels of bycatch. The SEZ, if triggered, would be re-opened following a specified time interval or when certain bycatch reduction thresholds were met.

As of 2019, the SEZ has been closed twice because of at least two observed false killer whale M&SI within the Hawaiian EEZ in a given year. The first SEZ closure occurred in July 2018 (83 FR 33848; July 17, 2018) and the area was closed through December 31, 2018. The second SEZ closure occurred in February 2019 (84 FR 5356; February 21, 2019) and the area was closed through August 24, 2020 (85 FR 50959; August 19, 2020). The FKWTRT has held numerous calls in order to reach consensus on modifying the FKWTRP. A revised FKWTRP based on consensus to reduce M&SI is anticipated sometime in 2020.

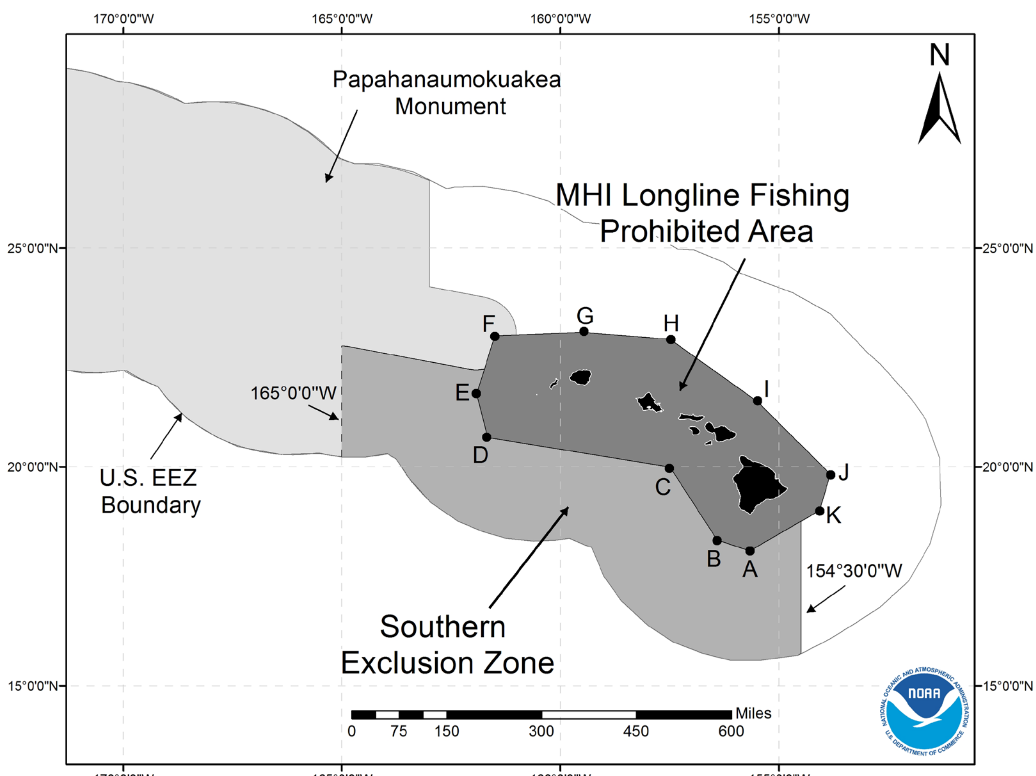

Figure 4–1. Hawai'i-based commercial longline fishing management areas.

The four regulatory measures to improve captain and crew response to hooked or entangled marine mammals include training and certification for vessel owners and captains in marine mammal handling and release techniques and best practices for avoiding interactions, a requirement for the vessel crew to inform the captain of any hooked or entangled marine mammal, a requirement for captains to supervise marine mammal handling and release, and a requirement to post NOAA Fisheries-approved marine mammal handling and release informational placards on longline vessels.

The FKWTRP also includes six non-regulatory measures, or actions not required by regulations, but which NOAA Fisheries is carrying out to improve data quality, efficiency, and dissemination to the FKWTRT and the public. These measures are improving our ability to understand and manage false killer whale bycatch. From these measures NOAA Fisheries has: adjusted the NOAA Fisheries observer program's sampling strategy and observer allocation to allow a more precise marine mammal bycatch estimate to be calculated; made specific changes to observer training and data collection protocols to gather information that will help us to better understand the nature of false killer whale interactions with longline gear; notified the FKWTRT when there is an observed interaction of a known or possible false killer whale; expedited the injury determination of false killer whale interactions with the longline fishery; expedited the processing of data from NOAA Fisheries' Hawaiian Islands Cetacean and Ecosystem Assessment Surveys, which resulted in updated abundance estimates for all cetaceans in Hawaiian waters, including false killer whales (see Bradford et al. 2018); and periodically reconvened the FKWTRT to monitor the success of the plan and evaluate any new information.

As discussed in the final 2017 SAR (Carretta et al. 2018), for the 5-year period prior to the implementation of the FKWTRP (2008–2012), the average estimated M&SI to MHI IFKWs in the deep-set longline fishery (0.21 animals per year) exceeded PBR (0.18 animals per year). Because of the significant regulatory change in longline fishery activity relative to MHI IFKWs under the FKWTRP, the status of the MHI IFKW is assessed relative to the post-TRP period (2013–2015). For this period, the estimate of M&SI (0.01) is below PBR (0.3) (Carretta et al. 2018). However, the total M&SI to MHI IFKWs cannot be considered to be insignificant and approaching zero, as it is greater than 10% of PBR. Additionally, other variables may have contributed to the changes in M&SI rates in these fisheries including adjustments to the proration method assigning interactions to different blackfish species and populations, shifts in fishing effort because of the expanded boundary of the Papahānaumokuākea Marine National Monument, and others.

While conservation measures implemented through the FKWTRP, particularly closure zones, may have reduced the threat of incidental interactions from commercial longline fisheries to MHI IFKWs, additional monitoring of bycatch rates for the MHI IFKW over time will be required before determining whether take-reduction measures of the FKWTRP, including the LLEZ, have definitively reduced fishery takes below PBR. Additionally, the FKWTRP only addresses threats from commercial longline fisheries and does not address threats from non-longline commercial and recreational fisheries (e.g., troll, kaka line, short line fisheries, etc.). Moreover, the FKWTRP has the potential to increase effort in the shortline fishery, potentially inside the LLEZ, as noted by fishermen who were part of the FKWTRT back in 2010.

4.3 Active Research Programs to Fill Data Gaps

Effective conservation of a cetacean population requires an understanding of population structure, abundance, habitat use, natural and anthropogenic threats, and estimates of reproduction and mortality rates. A number of federal and non-federal research programs have been conducting research on false killer whales and other Hawaiian odontocetes for more than three decades. This research has been integral in determining genetic and social structure of false killer whale populations in Hawaiʻi (e.g., Baird et al. 2008, Chivers et al. 2010, Martien et al. 2011, Martien et al. 2014a, 2014b), defining the MHI IFKW as a DPS under the ESA (Oleson et al. 2010, Oleson et al. 2012), identifying biologically important areas of habitat (e.g., Baird et al. 2010, Baird et al. 2012, Baird et al. 2015a), researching gear modifications to reduce bycatch rates during depredation events, and determining contaminant loads in both free-ranging (Ylitalo et al. 2009, Foltz et al. 2014) and stranded (Bachman et al. 2014) individuals. Further research will continue to refine our knowledge of the MHI IFKW.

Since MHI IFKWs, along with pelagic and NWHI false killer whales, all have the potential to interact with pelagic longline fisheries in Hawaiian waters, using passive acoustic monitoring to distinguish false killer whales' acoustic signals from those of other toothed whales has been identified as a primary research goal in the FKWTRP (77 FR 71259; November 29, 2012). Based on results from Baumann-Pickering et al. (2015) on the classification of echolocation clicks and published work on whistle discrimination, passive acoustic monitoring of false killer whales (i.e., discriminating false killer whales from other species such as short-finned pilot whales) has the potential to be reliable with high accuracy. This may lead to new potential methods for management and bycatch mitigation by investigating long-term trends in cetacean behavior and ecology. Additionally, by including passive acoustic recorders on fishing gear or hydrophones attached to longline fishing vessels, researchers may be able to identify behavioral patterns, confirm species of bycaught animals, or implement real-time alarm systems. Barkley et al. (2019) took passive acoustic monitoring a step further and investigated whether false killer whale whistles could be correctly classified to population based on their characteristics to serve as a method of identifying populations when genetic or photo-ID data are unable. Results suggest that the time-frequency whistle characteristics are not suitable to confidently classify encounters to a specific false killer whale population (i.e., MHI IFKW, pelagic, or NWHI), although certain features of whistles produced by MHI IFKWs allow for overall higher classification accuracy. Inclusion of other vocalization types, such as echolocation clicks, and alternative whistle variables may improve correct classification success for these sympatric populations (Barkley et al. 2019).

Other research being conducted on MHI IFKWs includes expanding the photo-ID database, identifying additional social structure, using drones for breath sample collection to examine respiratory microbiome (e.g., Lerma et al. 2019), continued satellite tag deployment for assessment of spatial use, and biopsy samples for epigenetic research to assess age relationships (Baird 2019a).

4.4 Outreach and Education

NOAA Fisheries has produced a new web site, featured news stories, and developed informational videos about false killer whales in Hawaiʻi (available at https://www.fisheries.noaa.gov/species/false-killer-whale#overview). NOAA Fisheries is committed to working with the school age children, community groups, and other organizations to provide educational opportunities about all marine protected species through seminars, community events, and literature. Cascadia Research Collective has produced a number of videos distributed online and through social media, and produced and distributed a variety of educational materials aimed at various target groups in Hawaiʻi (available at http://www.cascadiaresearch.org/hawaiian-cetacean-studies/false-killer-whales-hawaii). It is through these efforts as well as collaborative efforts with state and federal agencies that a more well-informed public can make a difference through responsible decision making as it pertains to false killer whales and the marine environment.

Marine Wildlife Viewing Guidelines

Watching marine animals in their natural habitat can be a positive way to promote conservation and respect for the animals and the marine environment. However, irresponsible human behavior can disturb animals, destroy important habitats, and even result in injury to animals and people. To promote responsible and sustainable marine animal viewing, NOAA Fisheries has developed numerous outreach programs, viewing guidelines and regulations, and enforcement actions. While these guidelines do not explicitly mention MHI IFKWs, they do provide guidelines for responsibly viewing dolphins and whales in general.

Marine wildlife viewing guidelines promoted by NOAA Fisheries and NOAA's National Marine Sanctuaries include, but are not limited to, the following: learn about the species before you go; view from a distance; hands off wildlife; do not feed or attract marine wildlife; never chase or harass wildlife; lend a hand with trash removal; help others to become responsible wildlife watchers and tour operators; and report sick or injured animals to the NOAA statewide hotline at 1-888-256-9840.

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