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U.S. PACIFIC MARINE MAMMAL STOCK ASSESSMENTS: 2017

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Stock assessment reports and appendices revised in 2017. Reports for other species and stocks are available in previous editions of the Pacific Region Stock Assessment Reports.

PINNIPEDS

CETACEANS - U.S. WEST COAST

CETACEANS – HAWAII & WESTERN PACIFIC

APPENDICES

PREFACE

Under the 1994 amendments to the Marine Mammal Protection Act (MMPA), the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) are required to publish Stock Assessment Reports for all stocks of marine mammals within U.S. waters, to review new information every year for strategic stocks and every three years for non-strategic stocks, and to update the stock assessment reports when significant new information becomes available.

Pacific region stock assessments include those studied by the Southwest Fisheries Science Center (SWFSC, La Jolla, CA), the Pacific Islands Fisheries Science Center (PIFSC, Honolulu, HI), the National Marine Mammal Laboratory (NMML, Seattle, WA), and the Northwest Fisheries Science Center (NWFSC, Seattle, WA). The 2017 Pacific marine mammal stock assessments include revised reports for 35 Pacific marine mammal stocks under NMFS jurisdiction, including 9 "strategic" stocks: Hawaiian monk seal, Eastern North Pacific blue whale, Southern Resident killer whale, California/Oregon/Washington humpback whale, Hawaii sperm whale, Central North Pacific blue whale, Hawaii fin whale, Hawaii sei whale, and Main Hawaiian Islands Insular false killer whale. The status of Hawaii Pelagic false killer whale has changed from strategic to non-strategic because the 5-year annual mean human-caused serious injury and mortality is currently below PBR. New abundance estimates are available for 4 U.S. west coast stocks: Cuvier's beaked whale, *Mesoplodont* beaked whales, Baird's beaked whale, and Southern Resident killer whales. New information on fishery-related serious injury and mortality has been updated for those stocks where possible. Updated estimates of stock abundance are also available for many Pacific Islands region stocks, based on a new analysis of a 2010 pelagic line-transect survey in the region (Bradford *et al.* 2017a), a mark-recapture photo-ID analysis of Hawaii Insular false killer whales (Bradford *et al.* 2017b) and completed 2015 field studies of Hawaiian monk seals (Johanos 2017a). Updated estimates of abundance are available for the following Pacific Islands stocks: Hawaiian monk seal, Hawaii rough-toothed dolphin, Hawaii Risso's dolphin, Hawaii Pelagic bottlenose dolphin, Hawaii Pelagic pantropical spotted dolphin, Hawaii Pelagic striped dolphin, Hawaii Fraser's dolphin, Hawaiian Islands melon-headed whale, Hawaii pygmy killer whale, Main Hawaiian Islands Insular false killer whale, Hawaii killer whale, Hawaii short-finned pilot whale, Hawaii Pelagic Blainville's beaked whale, Hawaii Longman's beaked whale, Hawaii Pelagic Cuvier's beaked whale, Hawaii sperm whale, Central North Pacific blue whale, Hawaii fin whale, and Hawaii sei whale. Updated estimates of abundance are available for California Current beaked whales, based on a recent trend-based analysis (Moore and Barlow 2017). New information on human-caused serious injury and mortality is included for California/Oregon/Washington stocks of humpback whale and the Eastern North Pacific stock of blue whale.

This is a working document and individual stock assessment reports will be updated as new information on marine mammal stocks and fisheries becomes available. Background information and guidelines for preparing stock assessment reports are reviewed in Wade and Angliss (1997). The authors solicit any new information or comments which would improve future stock assessment reports.

Draft versions of the 2017 stock assessment reports were reviewed by the Pacific Scientific Review Group at the February 2017 meeting.

These Stock Assessment Reports summarize information from a wide range of original data sources and an extensive bibliography of all sources is given in each report. We recommend users of this document refer to and cite *original* literature sources cited within the stock assessment reports rather than citing this report or previous Stock Assessment Reports.

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HAWAIIAN MONK SEAL (*Neomonachus schauinslandi*)

STOCK DEFINITION AND GEOGRAPHIC RANGE

Hawaiian monk seals are distributed throughout the Northwestern Hawaiian Islands (NWHI), with subpopulations at French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, Kure Atoll, and Necker and Nihoa Islands. They also occur throughout the main Hawaiian Islands (MHI). Genetic variation among monk seals is extremely low and may reflect a long-term history at low population levels and more recent human influences (Kretzmann *et al.* 1997, 2001, Schultz *et al.* 2009). Though monk seal subpopulations often exhibit asynchronous variation in demographic parameters (such as abundance trends and survival rates), they are connected by animal movement throughout the species' range (Johanos *et al.* 2013). Genetic analysis (Schultz *et al.* 2011) indicates the species is a single panmictic population. The Hawaiian monk seal is therefore considered a single stock. Scheel *et al.* (2014) established a new genus, *Neomonachus*, comprising the Caribbean and Hawaiian monk seals, based upon molecular and skull morphology evidence.

POPULATION SIZE

The best estimate of the total population size is 1,324 (95% confidence interval 1,263-1,430; CV = 0.03), (Table 1, Baker *et al.* 2016, Johanos 2017a,b,c). In 2015, NWHI field camp durations were longest in duration since 2011, with the exception of Midway Atoll. This allowed for more thorough demographic studies. In 2016, new approaches were developed to estimate Hawaiian monk seal abundance, both range-wide and at individual subpopulations (Baker *et al.* 2016, Harting *et al.* 2017). In brief, methods for abundance estimation vary by site and year depending on the type and quantity of data available. Total enumeration is the favored method, but requires sufficient field presence to convincingly identify all the seals present, which is typically not achieved at most sites (Baker *et al.* 2006). When total enumeration is not possible, capture-recapture estimates (using Program CAPTURE) are conducted (Baker 2004; Otis *et al.* 1978, Rexstad & Burnham 1991, White *et al.* 1982). When no reliable estimator is obtainable in Program CAPTURE (i.e., the model selection criterion is < 0.75, following Otis *et al.* 1978), total non-pup abundance is estimated using pre-existing information on the relationship between proportion of the population identified and field effort hours expended (referred to as discover curve analysis). At rarely visited sites (Necker, Nihoa, Niihau and Lehua Islands) where data are insufficient to use any of the above methods, beach counts are corrected for the proportion of seals at sea. At all sites, pups are tallied. Finally, site-specific abundance estimates and their uncertainty are combined using Monte Carlo methods to obtain a range-wide abundance estimate distribution. All the above methods are described or referenced in Baker *et al.* (2016) and Harting *et al.* 2017). Note that because some of the abundance estimation methods utilize empirical distributions which are updated as new data accrue, previous years' estimates can change slightly when recalculated using these updated distributions.

In 2015, total enumeration was achieved only at Kure Atoll, and a capture-recapture estimate was obtained for French Frigate Shoals. At Laysan Island, Lisianski Island, Pearl and Hermes Reef, and Midway Atoll abundance estimates were obtained using discovery curve analysis. Counts at Necker and Nihoa Islands are conducted from zero to a few times per year. Pups are born over the course of many months and have very different haulout patterns compared to older animals. Therefore, pup production at Necker and Nihoa Islands is estimated as the mean of the total pups observed in the past 5 years, excluding counts occurring early in the pupping season when most have yet to be born. There were no counts conducted at Necker Island in 2014 or 2015, so two beach counts conducted in 2013 were used to estimate abundance (no change in abundance since 2013 assumed). Three counts were conducted at Nihoa Island in 2015.

In the MHI, NMFS collects information on seal sightings reported throughout the year by a variety of sources, including a volunteer network, the public, and directed NMFS observation effort. In recent years, a small number of surveys of Ni'ihau and nearby Lehua Islands have been conducted through a collaboration between NMFS, Ni'ihau residents and the US Navy. Total MHI monk seal abundance is estimated by adding the number of individually identifiable seals documented in 2015 on all MHI other than Ni'ihau and Lehua to an estimate for these latter two islands based on counts expanded by a haulout correction factor. A recent telemetry study (Wilson *et al.* 2017) found that MHI monk seals (N=23) spent a greater proportion of time ashore than Harting *et al.* 2017) estimated for NWHI seals. Therefore, the total non-pup estimate for Ni'ihau and Lehua Islands was the total beach count at those sites (less individual seals already counted at other MHI) divided by the mean proportion of time hauled out in the MHI (Wilson *et al.* 2017). The total pups observed at Ni'ihau and Lehua Islands were added to obtain the total (Table 1).

Table 1. Total and minimum estimated abundance of Hawaiian monk seals by location in 2015. The estimation method is indicated for each site. Methods used include DC: discovery curve analysis, Enum: total enumeration; CR: capture-recapture; CC: counts corrected for the proportion of seals at sea; Min: minimum tally. Median values are presented. Note that the median range-wide abundance is not equal to the total of the individual sites' medians, because the median of sums may differ from the sum of medians for non-symmetrical distributions.

	Total			Minimum			
Location	Non-pups	Pups	Total	Non-pups	Pups	Total	Method
French Frigate Shoals	148	45	193	143	45	188	CR
Laysan	209	35	244	208	35	243	DC
Lisianski	133	18	151	133	18	151	DC
Pearl and Hermes Reef	118	27	145	118	27	145	DC
Midway	53	11	64	48	11	59	DC
Kure	78	12	90	78	12	90	Enum
Necker	59	5	64	49	5	54	CC
Nihoa	108	9	117	91	9	100	CC
MHI_(without Ni'ihau/ Lehua)	130	15	145	130	15	145	Min
Ni'ihau/Lehua	81	21	102	65	21	86	CC
Total	*1126*	*198*	***1324***	***1063***	*198*	***1261***	

Minimum Population Estimate

The total numbers of seals identified at the NWHI subpopulations other than Necker and Nihoa, and in the MHI other than Ni'ihau and Lehua, are the best estimates of minimum population size at those sites. Minimum population sizes for Necker, Nihoa, Ni'ihau, and Lehua Islands are estimated as the lower 20th percentiles of the non-pup abundance distributions generated using haulout corrections as described above, plus the pup estimates. The minimum abundance estimates for each site and for all sites combined (1,261) are presented in Table 1.

Current Population Trend

Range-wide abundance estimates are available only from 2013 to 2015 (Figure 1). While these estimates remain somewhat negatively-biased for reasons explained in Baker *et al.* (2016), they provided a much more comprehensive assessment of status and trends than has been previously available. The abundance estimates from 2013 to 2015 are encouraging—the point estimate for 2014 is higher than for 2013, and 2015 is even higher. The confidence intervals for all years largely overlap one another. Thus, it is not currently possible to unequivocally conclude whether the current trend is declining, stable, or increasing. A reliable conclusion regarding population trend will only be apparent after more annual range-wide abundance estimates have accrued.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Mean non-pup beach counts are used as a long-term index of abundance for years when data are insufficient to estimate total abundance as described above. Prior to 1999, beach count increases of up to 7% annually were observed at Pearl and Hermes Reef, and this is the highest estimate of the maximum net productivity rate (R_{max}) observed for this species (Johanos 2017a). Consistent with this value, a life table analysis representing a time when the MHI monk seal population was apparently expanding, yielded an estimated intrinsic population growth rate of 1.07 (Baker *et al.* 2011).

Figure 1. Range-wide abundance of Hawaiian monk seals (from Baker *et al.* 2016). Medians and 95% confidence limits are shown.
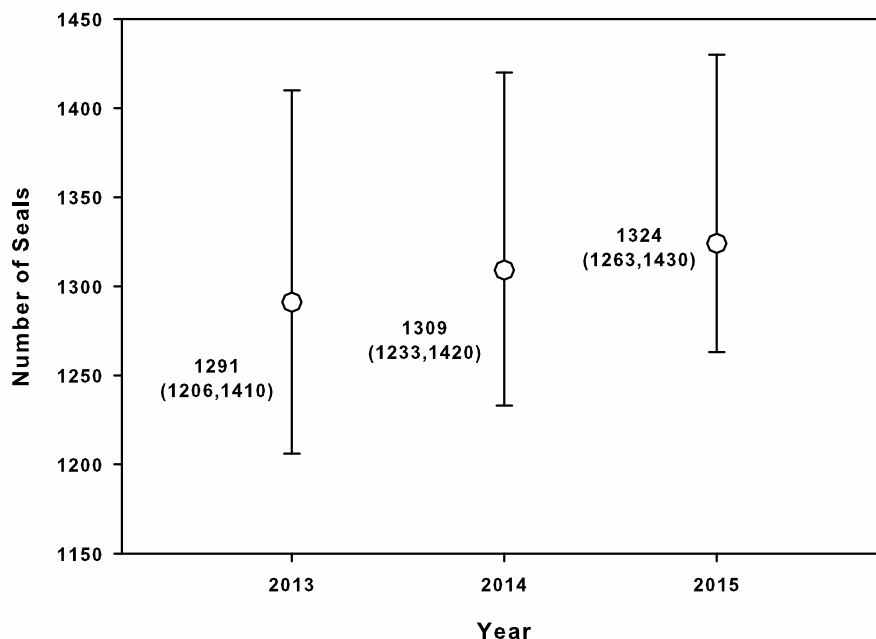
POTENTIAL BIOLOGICAL REMOVAL

Past reports have concluded that Hawaiian monk seal stock dynamics did not conform to the underlying model for calculating PBR such that PBR for the Hawaiian monk seal has been undetermined. That conclusion was based on the fact that the stock was declining despite being well below OSP (Optimum Sustainable Population level). The trend since 2013 (Figure 1) does not indicate the stock has continued to decline, so that PBR may be determined. Using current minimum population size (1,261), R_{max} (0.07) and a recovery factor (F_r) for ESA endangered stocks (0.1), yields a Potential Biological Removal (PBR) of 4.4.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Human-related mortality has caused two major declines of the Hawaiian monk seal (Ragen 1999). In the 1800s, this species was decimated by sealers, crews of wrecked vessels, and guano and feather hunters (Dill and Bryan 1912; Wetmore 1925; Bailey 1952; Clapp and Woodward 1972). Following a period of at least partial recovery in the first half of the 20th century (Rice 1960), most subpopulations again declined. This second decline has not been fully explained, but long-term trends at several sites appear to have been driven both by variable oceanic productivity (represented by the Pacific Decadal Oscillation) and by human disturbance (Baker *et al.* 2012, Ragen 1999, Kenyon 1972, Gerrodette and Gilmartin 1990). Currently, human activities in the NWHI are limited and human disturbance is relatively rare, but human-seal interactions, have become an important issue in the MHI. Intentional killing of seals in the MHI is an ongoing and serious concern (Table 2).

Table 2. Intentional and potentially intentional killings of MHI monk seals, and anthropogenic mortalities not associated with fishing gear since 2011 (Johanos 2015d).

Year	Age/sex	Island	Cause of Death	Comments
2011	Adult male	Molokai	Skull fracture, blunt force trauma	Intent unconfirmed
	Juvenile female	Molokai	Skull fracture, blunt force trauma	Intent unconfirmed
2012	Juvenile male	Kauai	Gunshot wound	
	Subadult male	Kauai	Skull fracture	Intent unconfirmed
2014	Adult male	Oahu	Suspected trauma	Intent unconfirmed

	Pup female	Kauai	Skull fracture, blunt force trauma	Likely intentional
	Pup male	Kauai	Dog attack/bite wounds	4 other seals injured during this event
2015	Juvenile male	Kauai	Probable boat strike	
	Adult male	Laysan	Research handling	Accidental, specific cause undetermined

In September 2015, an adult male monk seal died during health assessment research. Nothing was identified in the subsequent necropsy to suggest an underlying health concern that contributed to the seal's death. Histopathology of all major organs identified incidental age-related findings in multiple organs but none that would have predisposed this seal to mortality or contributed to cause of death. Thus, this mortality was deemed solely due to research capture and handling. In the past 10 years (2006-2015) one monk seal died as a result of enhancement activities (in 2006) and two died during research (in 2007 and the adult male described above 2015) (Johanos 2015d).

It is extremely unlikely that all carcasses of intentionally killed monk seals are discovered and reported. Studies of the recovery rates of carcasses for other marine mammal species have shown that the probability of detecting and documenting most deaths (whether from human or natural causes) is quite low (Peltier *et al.* 2012; Williams *et al.* 2011; Perrin *et al.* 2011; Punt and Wade 2010).

Fishery Information

Fishery interactions with monk seals can include direct interaction with gear (hooking or entanglement), seal consumption of discarded catch, and competition for prey. Entanglement of monk seals in derelict fishing gear, which is believed to originate outside the Hawaiian archipelago, is described in a separate section. Fishery interactions are a serious concern in the MHI, especially involving nearshore fisheries managed by the State of Hawaii (Gobush *et al.* 2016). There are no fisheries operating in or near the NWHI. In 2015, 11 seal hookings were documented (Henderson 2017a). Among these were two serious injuries and one mortality. The latter was a weaned female pup who ingested a hook. The hook was surgically removed but the pup succumbed to post-surgical complications. The remaining 8 hookings were classified as non-serious injuries, although 2 of these would have been deemed serious had they not been mitigated. Several incidents involved hooks used to catch ulua (jacks, *Caranx* spp.). Nearshore gillnets became a more common source of mortality in the 2000s, with three seals confirmed dead in these gillnets (2006, 2007, and 2010), and one additional seal in 2010 may have also died in similar circumstances but the carcass was not recovered. No gillnet-related mortality or injuries have been documented since 2010. Most reported hookings and gillnet entanglements have occurred since 2000 (Henderson 2017a). The MHI monk seal population appears to have been increasing in abundance during this period (Baker *et al.* 2011). No mortality or serious injuries have been attributed to the MHI bottomfish handline fishery (Table 3). Published studies on monk seal prey selection based upon scat/spew analysis and video from seal-mounted cameras revealed evidence that monk seals fed on families of bottomfish which contain commercial species (many prey items recovered from scats and spews were identified only to the level of family; Goodman-Lowe 1998, Longenecker *et al.* 2006, Parrish *et al.* 2000). Quantitative fatty acid signature analysis (QFASA) results support previous studies illustrating that monk seals consume a wide range of species (Iverson *et al.* 2011). However, deepwater-slope species, including two commercially targeted bottomfishes and other species not caught in the fishery, were estimated to comprise a large portion of the diet for some individuals. Similar species were estimated to be consumed by seals regardless of location, age or gender, but the relative importance of each species varied. Diets differed considerably between individual seals. These results highlight the need to better understand potential ecological interactions with the MHI bottomfish handline fishery.

Table 3. Summary of mortality, serious and non-serious injury of Hawaiian monk seals due to fisheries and calculation of annual mortality rate. n/a indicates that sufficient data are not available. Percent observer coverage for the deep and shallow-set components, respectively, of the pelagic longline fishery, are shown. Total non-serious injuries are presented as well as, in parentheses, the number of those injuries that would have been deemed serious had they not been mitigated (e.g., by de-hooking or disentangling). Data for MHI bottomfish and nearshore fisheries are based upon incidental observations (i.e., hooked seals and those entangled in active gear). All hookings not clearly attributable to either fishery with certainty were attributed to the bottomfish fishery, and hookings which resulted in injury of unknown severity were classified as serious. Nearshore fisheries injuries and mortalities include seals entangled/drowned in nearshore gillnets and hooked/entangled in hook-and-line gear, recognizing that it is not possible to determine whether the nets or hook-and-line gear involved were being used for commercial purposes.

Fishery Name	Year	Data	% Obs.	Observed/Reported	Estimated	Non-serious	Mean

		Type	coverage	Mortality/Serious Injury	Mortality/ Serious Injury	(Mitigated serious)	Takes (CV)
Pelagic Longline	2011 2012 2013 2014 2015	observer observer observer observer observer	20.3% & 100% 20.4% & 100% 20.4% & 100% 20.8% & 100% 20.6% & 100%	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 (0)
MHI Bottomfish	2011 2012 2013 2014 2015	Incidental observations of seals	none	0 0 0 0 0	n/a	0 0 0 0 0	n/a
Nearshore	2011 2012 2013 2014 2015	Incidental observations of seals	none	0 4 0 1 3	n/a	9 (3) 12 (5) 15 (6) 13 (9) 8 (2)	≥1.6
Minimum total annual takes							≥ 1.6

Fishery Mortality Rate

Total fishery mortality and serious injury is not considered to be insignificant and approaching a rate of zero. Monk seals are being hooked and entangled in the MHI at a rate that has not been reliably assessed but is certainly greater than zero. The information above represents only reported direct interactions, and without directed observation effort, the true interaction rate cannot be estimated. Monk seals also die from entanglement in fishing gear and other debris throughout their range (likely originating from various sources outside of Hawaii), and NMFS along with partner agencies is pursuing a program to mitigate entanglement (see below).

Entanglement in Marine Debris

Hawaiian monk seals become entangled in fishing and other marine debris at rates higher than reported for other pinnipeds (Henderson 2001). A total of 361 cases of seals entangled in fishing gear or other debris have been observed from 1982 to 2015 (Henderson 2001; Henderson 2017b). Nine documented deaths resulted from entanglement in marine debris (Henderson 1990, 2001; Henderson 2017b). The fishing gear fouling the reefs and beaches of the NWHI and entangling monk seals only rarely includes types used in Hawaii fisheries. For example, trawl net and monofilament gillnet accounted for approximately 35% and 34%, respectively, of the debris removed from reefs in the NWHI by weight, and trawl net alone accounted for 88% of the debris by frequency (Donohue *et al.* 2001), despite the fact that trawl fisheries have been prohibited in Hawaii since the 1980s.

The NMFS and partner agencies continue to mitigate impacts of marine debris on monk seals as well as turtles, coral reefs and other wildlife. Marine debris is removed from beaches and seals are disentangled during annual population assessment activities at the main reproductive sites. Since 1996, annual debris survey and removal efforts in the NWHI coral reef habitat have been ongoing (Donohue *et al.* 2000, Donohue *et al.* 2001, Dameron *et al.* 2007).

Other Mortality

Sources of mortality that impede recovery include food limitation (see Habitat Issues), single and multiple-male intra-species aggression (mobbing), shark predation, and disease/parasitism. Male seal aggression has caused episodes of mortality and injury. Past interventions to remove aggressive males greatly mitigated, but have not eliminated, this source of mortality (Johanos *et al.* 2010). Galapagos shark predation on monk seal pups has been a chronic and significant source of mortality at French Frigate Shoals since the late 1990s, despite mitigation efforts by NMFS (Gobush 2010). Infectious disease effects on monk seal demographic trends are low relative to other stressors. However, land-to-sea transfer of *Toxoplasma gondii,* a protozoal parasite shed in the feces of cats, is of growing concern. A case definition for toxoplasmosis and other protozoal-related mortalities was developed and retrospectively applied to 306 cases of monk seal mortality from 1982-2015 (Barbieri *et al.* 2016). Eight monk seal mortalities (and 1 suspect mortality) have been directly attributed to toxoplasmosis from 2001 to 2015. The number of mortalities from

this pathogen are likely underrepresented, given that more seals disappear each year than are found dead and examined. Furthermore, *T. gondii* can be transmitted vertically from dam to fetus, and failed pregnancies are difficult to detect in wild, free-ranging animals. Unlike threats such as hook ingestion or malnutrition, which can often be mitigated through rehabilitation, options for treating seals with toxoplasmosis are severely restricted. The accumulating number of monk seal deaths from toxoplasmosis in recent years is a growing concern given the increasing geographic overlap between humans, cats, and Hawaiian monk seals in the MHI. Furthermore, the consequences of a disease outbreak introduced from livestock, feral animals, pets or other carrier wildlife may be catastrophic to the immunologically naïve monk seal population. Key disease threats include West Nile virus, morbillivirus and influenza.

Habitat Issues

Poor juvenile survival rates and variability in the relationship between weaning size and survival suggest that prey availability has limited recovery of NWHI monk seals (Baker and Thompson 2007, Baker *et al.* 2007, Baker 2008). Multiple strategies for improving juvenile survival, including translocation and captive care are being implemented (Baker and Littnan 2008, Baker *et al.* 2013, Norris 2013). A testament to the effectiveness of past actions to improve survival, Harting *et al.* (2014) demonstrated that approximately one-third of the monk seal population alive in 2012 was made up of seals that either had been intervened with to mitigate life-threatening situations, or were descendants of such seals. In 2014, NMFS produced a final Programmatic Environmental Impact Statement (PEIS) on current and future anticipated research and enhancement activities and issued a permit covering the activities described in the PEIS preferred alternative. A major habitat issue involves loss of terrestrial habitat at French Frigate Shoals, where some pupping and resting islets have shrunk or virtually disappeared (Antonelis *et al.* 2006). Projected increases in global average sea level may further significantly reduce terrestrial habitat for monk seals in the NWHI (Baker *et al.* 2006, Reynolds *et al.* 2012).

Goodman-Lowe (1998) provided information on prey selection using hard parts in scats and spewings. Information on at-sea movement and diving is available for seals at all six main subpopulations in the NWHI using satellite telemetry (Stewart *et al.* 2006). Cahoon (2011) and Cahoon *et al.* (2013) described diet and foraging behavior of MHI monk seals, and found no striking difference in prey selection between the NWHI and MHI.

Remains of the seawall at Tern Island, French Frigate Shoals, is an entrapment hazard for seals. Vessel groundings pose a continuing threat to monk seals and their habitat, through potential physical damage to reefs, oil spills, and release of debris into habitats.

Monk seal juvenile survival rates are favorable in the MHI (Baker *et al.* 2011). Further, the excellent condition of pups weaned on these islands suggests that there are ample prey resources available, perhaps in part due to fishing pressure that has reduced monk seal competition with large fish predators (sharks and jacks) (Baker and Johanos 2004). Yet, there are many challenges that may limit the potential for growth in this region. The human population in the MHI is approximately 1.4 million compared to fewer than 100 in the NWHI, such that anthropogenic threats in the MHI are considerable. Intentional killing of seals is a very serious concern. Also, the same fishing pressure that may have reduced the monk seal's competitors is a source of injury and mortality. Vessel traffic in the populated islands includes risk of collision with seals and impacts from oil spills. A mortality in 2015 was deemed most likely due to boat strike. Finally, as noted above, toxoplasmosis is now recognized as a serious anthropogenic threat to seals in the MHI.

STATUS OF STOCK

In 1976, the Hawaiian monk seal was designated depleted under the Marine Mammal Protection Act of 1972 and as endangered under the Endangered Species Act of 1973. Therefore, the Hawaiian monk seal is a strategic stock. The species is well below its optimum sustainable population and has not recovered from past declines. Annual human-caused mortality for the most recent 5-year period (2011-2015) was at least 3.4 animals, including fishery-related mortality in nearshore gillnets and hook-and-line gear (>=1.6/yr, Table 3), intentional killings and other human-caused mortalities (>=1.8/yr, Table 2).

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KILLER WHALE (*Orcinus orca*):
Eastern North Pacific Southern Resident Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Killer whales have a cosmopolitan distribution, ranging from equatorial to polar waters, with highest densities found in coastal temperate waters (Forney and Wade 2006). Along the west coast of North America, killer whales occur along the entire Alaskan coast as far north as Barrow (George et al. 1994, Lowry *et al*. 1987, Clarke *et al*. 2013), in British Columbia and Washington inland waterways (Bigg *et al*. 1990), and along the outer coasts of Washington, Oregon, and California (Barlow and Forney 2007). Seasonal and year-round occurrence has been noted for killer whales throughout Alaska (Braham and Dahlheim 1982) and in the intra-coastal waterways of British Columbia and Washington State, where pods have been labeled as 'resident,' 'transient,' and 'offshore' (Bigg *et al*. 1990, Ford *et al*. 1994) based on aspects of morphology, ecology, genetics, and behavior (Ford and Fisher 1982, Baird and Stacey 1988, Baird *et al*. 1992, Hoelzel *et al*. 1998). Through examination of photographs of recognizable individuals and pods, movements of whales between Prince William Sound and Kodiak Island have been observed (Matkin et al. 1999) and whales identified in Southeast Alaska have been observed in Prince William Sound, British Columbia, and Puget Sound (Leatherwood et al. 1990, Dahlheim *et al*. 1997).

Genetic studies provide evidence that the 'resident' and 'transient' types are distinct (Stevens *et al.* 1989, Hoelzel 1991, Hoelzel and Dover 1991, Hoelzel *et al.* 1998, Morin *et al.* 2010). Analyses of complete mitochondrial genomes indicates that transient killer whales should be recognized as a separate species, and that, pending additional data, resident killer whales should be recognized as a separate subspecies (Morin *et al.* 2010). The genetic data results support previous lines of evidence for separation of the transient and resident ecotypes, including differences in 1) acoustic dialects; 2) skull features; 3) morphology; 4) feeding specializations; and 5) a lack of interbreeding between the two sympatric ecotypes (Krahn *et al.* 2004).

Most sightings of the Eastern North Pacific Southern Resident stock of killer whales have occurred in the summer in inland waters of Washington and southern British Columbia. However, pods belonging to this stock have also been sighted in coastal waters off southern Vancouver Island and Washington (Bigg *et al*. 1990, Ford *et al*. 2000, NWFSC unpubl. data). The complete winter range of this stock is uncertain. Of the three pods comprising this stock, one (J1) is commonly sighted in inshore waters in winter, while the other two (K1 and L1) apparently spend more time offshore (Ford *et al*. 2000). These latter two pods have been sighted as far south as Monterey Bay and central California in recent years. They sometimes have also been seen entering the inland waters of Vancouver Island through Johnstone Strait in the spring (Ford *et al*. 2000), suggesting that they may spend time along the outer coast of Vancouver Island during the winter. In June 2007, whales from L-pod were sighted off Chatham Strait, Alaska, the farthest north they have ever been documented (J. Ford, pers. comm.). Passive autonomous acoustic recorders have recently provided more information on the seasonal occurrence of these pods along the west coast of the U.S. (Hanson *et al*. 2013). In addition, satellite-linked tags were recently deployed in winter months on members of J, K, and L pods. Results were consistent with previous data, but provided much greater detail, showing
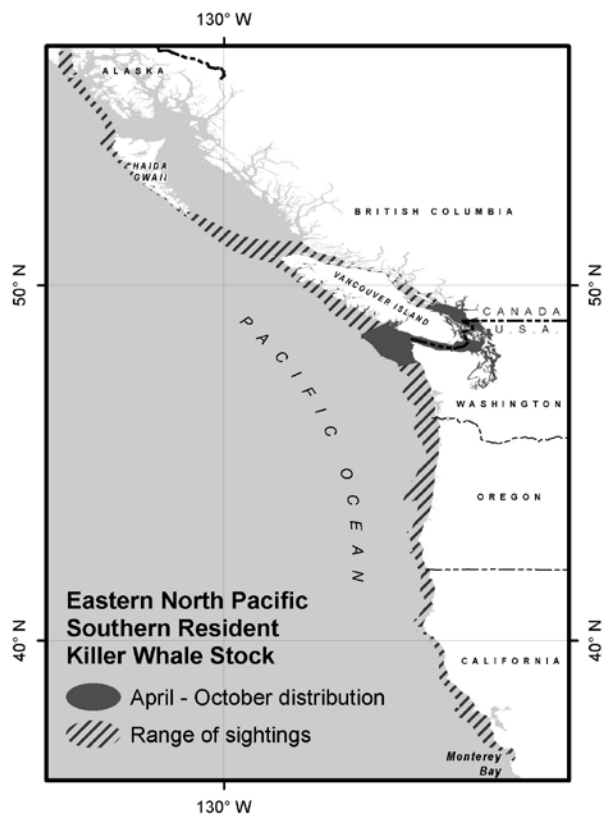

Figure 1. Approximate April - October distribution of the Eastern North Pacific Southern Resident killer whale stock (shaded area) and range of sightings (diagonal lines).

wide-ranging use of inland waters by J Pod whales and extensive movements in U.S. coastal waters by K and L Pods.

Based on data regarding association patterns, acoustics, movements, genetic differences and potential fishery interactions, eight killer whale stocks are recognized within the Pacific U.S. EEZ: 1) the Eastern North Pacific Alaska Resident stock - occurring from Southeast Alaska to the Bering Sea, 2) the Eastern North Pacific Northern Resident stock - occurring from British Columbia through Alaska, 3) the Eastern North Pacific Southern Resident stock - occurring mainly within the inland waters of Washington State and southern British Columbia but extending from central California into southern Southeast Alaska (see Fig. 1), 4) the West Coast Transient stock - occurring from Alaska through California, 5) the Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock - occurring from southeast Alaska to the Bering Sea, 6) the AT1 Stock – found only in Prince William Sound, 7) the Eastern North Pacific Offshore stock - occurring from Southeast Alaska through California, 8) the Hawaiian stock. The Stock Assessment Reports for the Alaska Region contain information concerning the Eastern North Pacific Alaska Resident, Eastern North Pacific Northern Resident and the Gulf of Alaska, Aleutian Islands, and Bering Sea, AT1, and Eastern North Pacific Transient stocks.

POPULATION SIZE

The Eastern North Pacific Southern Resident stock is a trans-boundary stock including killer whales in inland Washington and southern British Columbia waters. Photo-identification of individual whales through the years has advanced knowledge of this stock's structure, behaviors, and movements. In 1993, the three pods comprising this stock totaled 96 killer whales (Ford *et al.* 1994). The population increased to 99 whales in 1995, then declined to 79 whales in 2001, and most recently numbered 83 whales in 2016 (Fig. 2; Ford *et al.* 2000; Center for Whale Research 2016). The 2001-2005 counts included a whale born in 1999 (L-98) that was listed as missing during the annual census in May and June 2001 but was subsequently discovered alone in an inlet off the west coast of Vancouver Island. L-98 remained separate from L pod until 10 March 2006 when he died due to injuries associated with a vessel interaction in Nootka Sound. L-98 has been subtracted from the official 2006 and subsequent population censuses. The most recent census spanning 1 July 2015 through 1 July 2016 includes five new calves (three male, one female, one sex unknown) and the deaths of one of the calves (sex unknown), a post-reproductive age female, and young adult male reproductive age adult female (that was pregnant with a female neonate), and a calf of unknown sex. This does not include the mortality of two post-reproductive females, a reproductive age female and her dependent male calf, or a young adult male. Nor does this include a stillborn fetus that was observed being pushed at the surface by it presumed mother (Durban *et al.* 2016).

Minimum Population Estimate

The abundance estimate for this stock of killer whales is a direct count of individually identifiable animals. It is thought that the entire population is censused every year. This estimate therefore serves as both a best estimate of abundance and a minimum estimate of abundance.   Thus, the minimum population estimate (N_{min}) for the Eastern North Pacific Southern Resident stock of killer whales is 83 animals.

Figure 2. Population of Eastern North Pacific Southern Resident stock of killer whales, 1974-2016.   Each year's count includes animals first seen and first missed; a whale is considered first missed the year after it was last seen alive (Ford *et al.* 2000; Center for Whale Research 2016).

Current Population Trend

During the live-capture fishery that existed from 1967 to 1973, it is estimated that 47 killer whales, mostly immature, were taken out of this stock (Ford *et al.* 1994). Since the first complete census of this stock in 1974 when 71 animals were identified, the number of southern resident killer whales has fluctuated annually. Between 1974 and the mid-1990s, the Southern Resident stock increased approximately 35% (Ford *et al.* 1994), representing a net annual growth rate of 1.8% during those years. Following the peak census count of 99 animals in 1995, the population size has declined and currently stands at 83 animals as of the 2016 census (Ford *et al.* 2000; Center for Whale Research 2016).
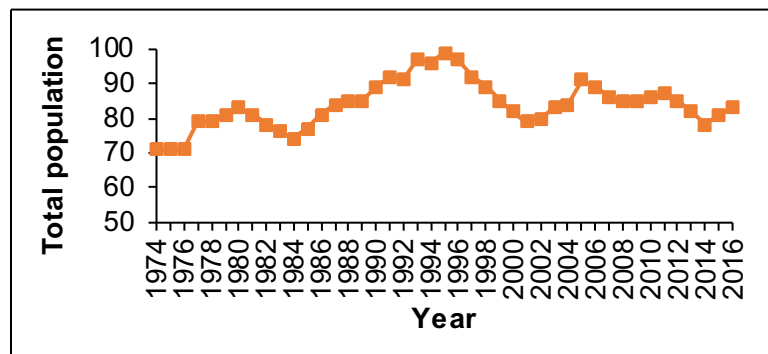
CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

A reliable estimate of the maximum net productivity rate is currently unavailable for this stock of killer whales. Matkin *et al.* (2014) estimated a maximum population annual growth rate of 1.035 for southern Alaska resident killer whales. The authors noted that the 3.5% annual rate estimated for southern Alaska residents is higher than previously measured rates for British Columbia northern residents (2.9%, Olesiuk *et al.* 1990) and "probably represents a population at r-max (maximum rate of growth)." In the absence of published estimates of R_{max} for southern resident killer whales, the maximum annual rate of 3.5% found for southern Alaska residents is used for this stock of southern resident killer whales. This reflects more information about the known life history of resident killer whales than the default R_{max} of 4% and results in a more conservative estimate of potential biological removal (PBR).

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (83) <u>times</u> one-half the maximum net growth rate for *Alaska* resident killer whales (½ of 3.5%) <u>times</u> a recovery factor of 0.1 (for an endangered stock, Wade and Angliss 1997), resulting in a PBR of 0.14 whales per year, or approximately 1 animal every 7 years.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

Salmon drift gillnet fisheries in Washington inland waters were last observed in 1993 and 1994 and no killer whale entanglements were documented, though observer coverage levels were less than 10% (Erstad *et al.* 1996, Pierce *et al.* 1994, Pierce *et al.* 1996, NWIFC 1995). Fishing effort in the inland waters drift gillnet fishery has declined considerably since 1994 because far fewer vessels participate today (NOAA West Coast Region). Past marine mammal entanglements in this fishery included harbor porpoise, Dall's porpoise, and harbor seals. Coastal marine tribal set gillnets also occur along the outer Washington coast and no killer whale interactions have been reported in this fishery since the inception of the observer program in 1988, though the fishery is not active every year (Gearin *et al.* 1994, Gearin *et al.* 2000, Makah Fisheries Management).

An additional source of information on killer whale mortality and injury incidental to commercial fishery operations is the self-reported fisheries information required of vessel operators by the MMPA. No self-report records of killer whale mortality have been reported.

Due to a lack of observer programs, there are few data concerning the mortality of marine mammals incidental to Canadian commercial fisheries. Since 1990, there have been no reported fishery-related strandings of killer whales in Canadian waters. However, in 1994 one killer whale was reported to have contacted a salmon gillnet but did not entangle (Guenther *et al.* 1995). Data regarding the level of killer whale mortality related to commercial fisheries in Canadian waters are not available.

The known total fishery mortality and serious injury for this stock is zero.

Other Mortality

No human-caused killer whale mortality or serious injuries were reported from non-fisheries sources in 2011-2015 (Carretta *et al.* 2017). In 2012, a moderately decomposed juvenile female southern resident killer whale (L-112) was found dead near Long Beach, WA. A full necropsy was performed and the cause of death was determined to be blunt force trauma to the head, however the source of the trauma (vessel strike, intraspecific aggression, or other unknown source) could not be established (NOAA 2014). There was documentation of a whale-boat collision in Haro Strait in 2005 which resulted in a minor injury to a whale. In 2006, whale L98 was killed during a vessel interaction. It is important to note that L98 had become habituated to regularly interacting with vessels during its isolation in Nootka Sound. The annual known level of non-fishery human-caused mortality for this stock over the past five years (2010-2014) is zero animals per year. In spring 2016, a young adult male, L95, was found to have died of a fungal infection that may have been related to a satellite tag deployment approximately 5 weeks prior to its death. In fall 2016 another young adult male, J34, was found dead in the northern Georgia Strait. The necropsy indicated that the whale died of blunt force trauma to the head and the source of trauma is still under investigation.

STATUS OF STOCK

Total annual fishery mortality and serious injury for this stock (0) is not known to exceed 10% of the calculated PBR (0.14) and, therefore, appears to be insignificant and approaching zero mortality and serious injury rate. The estimated annual level of human-caused mortality and serious injury of zero animals per year does not exceed the PBR (0.14). Southern Resident killer whales were formally listed as "endangered" under the ESA in 2005 and consequently the stock is automatically considered as a "strategic" stock under the MMPA. This stock was considered "depleted" (68 FR 31980, May 29, 2003) prior to its 2005 listing under the ESA (70 FR 69903, November 18, 2005).

Habitat Issues

Several potential risk factors identified for this population have habitat implications. The summer range of this population, the inland waters of Washington and British Columbia, are home to a large commercial whale watch industry, and high levels of recreational boating and commercial shipping. Potential for acoustic masking effects on the whales' communication and foraging due to vessel traffic remains a concern (Erbe 2002, Clark *et al.* 2009). In 2011 vessel approach regulations were implemented to restrict vessels from approaching closer than 200m. This population appears to be Chinook salmon specialists (Ford and Ellis 2006, Hanson *et al.* 2010, Ford *et al.* 2016), although other species, such as chum, pink, and coho salmon also appear to be important elements of the diet (Ford *et al.* 1998). There is evidence that changes in Chinook abundance have affected this population (Ford *et al.* 2009, Ward *et al.* 2009). In addition, the high trophic level and longevity of the animals has predisposed them to accumulate levels of contaminants that are high enough to cause potential health impacts. In particular, there is recent evidence of extremely high levels of flame retardants in young animals (Krahn *et al.* 2007, 2009).

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BAIRD'S BEAKED WHALE (*Berardius bairdii*):
California/Oregon/Washington Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Baird's beaked whales are distributed throughout deep waters and along the continental slopes of the North Pacific Ocean (Balcomb 1989, Macleod *et al.* 2006). They have been harvested and studied in Japanese waters, but little is known about this species elsewhere (Balcomb 1989). Along the U.S. west coast, Baird's beaked whales have been seen primarily along the continental slope (Figure 1) from late spring to early fall. They have been seen less frequently and are presumed to be farther offshore during the colder water months of November through April. For the Marine Mammal Protection Act (MMPA) stock assessment reports, Baird's beaked whales within the Pacific U.S. Exclusive Economic Zone are divided into two discrete, non-contiguous areas: 1) waters off California, Oregon and Washington (this report), and 2) Alaskan waters.
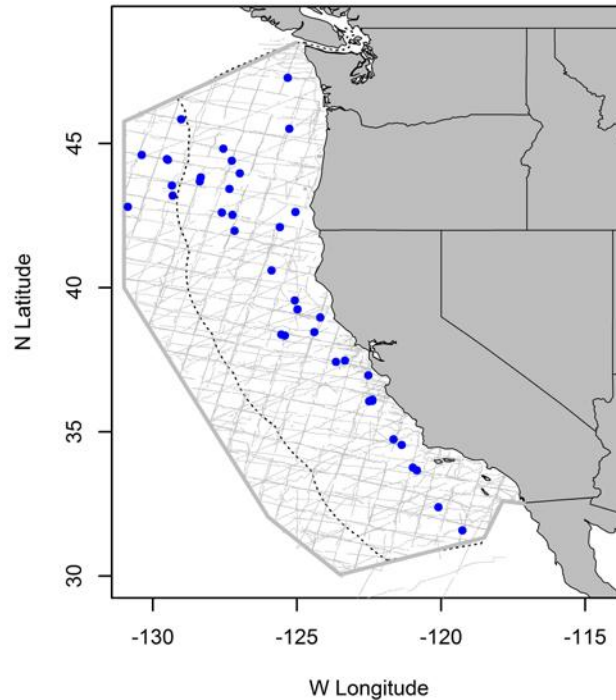
Figure 1. Baird's beaked whale sightings based on shipboard surveys off California, Oregon and Washington, 1991-2014 Dashed line represents the U.S. EEZ, thin lines indicate completed transect effort of all surveys combined.

POPULATION SIZE

Barlow (2016) recently estimated Baird's beaked whale abundance in the California Current at 5,394 (CV=0.83) and 7,960 (CV=0.93) whales for surveys conducted in 2008 and 2014, respectively. These estimates are higher than previously-published estimates for this region because they include lower estimates of trackline detection probability, *g(0)*, based on Beaufort sea state specific estimates of detectability for *Mesoplodon* species (Barlow 2015). A trend-based analysis of line-transect data from all surveys conducted between 1991 and 2014 yielded an estimate of abundance of 2,697 (CV=0.60) whales (Moore and Barlow 2017); these were based on newer (lower) *g(0)* estimates from earlier analyses, but were not as low as those used by Barlow (2016) and thus the abundance estimates are not as high (Moore and Barlow 2017). Based on this analysis and weak evidence for any trend in abundance, the recent 2014 estimate of 2,697 (CV=0.60) Baird's beaked whales is the most appropriate estimate for this stock.

Minimum Population Estimate

The log-normal 20th percentile of the 2014 abundance estimate is 1,633 Baird's beaked whales (Moore and Barlow 2017).

Current Population Trend

The analysis by Moore and Barlow (2013) did not suggest evidence of an abundance trend during 1991–2008 for Baird's beaked whale in waters off the U.S. west coast, but an updated analysis that includes 2014 survey data indicates that the population has remained stable or increased slightly (Moore and Barlow 2017 (Figure 2). An annual growth rate geometric mean (λ) of 1.02 (SD = 0.03) was estimated based on the

latest analysis, with 95% CRI ranging from 0.96 to 1.08 and a 72% chance of being positive (Moore and Barlow 2017).

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES
No information on current or maximum net productivity rates is available for this species.

POTENTIAL BIOLOGICAL REMOVAL
The potential biological removal (PBR) level for this stock is calculated as the minimum population size (1,633) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a species of unknown status with no fishery mortality; Wade and Angliss 1997), resulting in a PBR of 16 Baird's beaked whales per year.
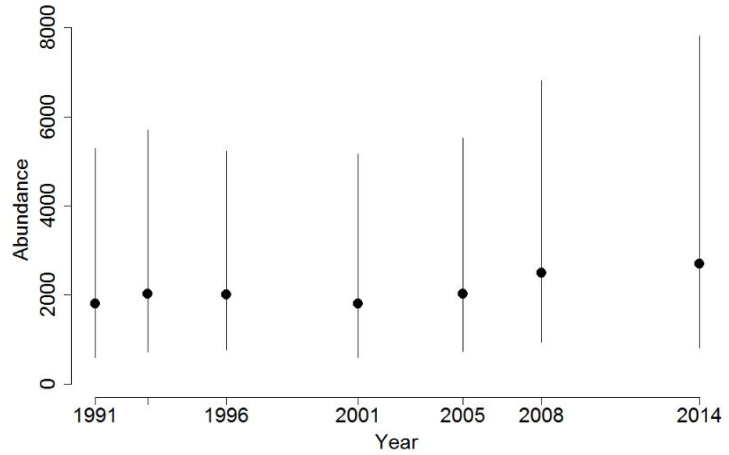
Figure 2. Abundance and trend estimates for Baird's beaked whales in the California Current, 1991-2014 (Moore and Barlow 2017). For each year, the Bayesian posterior median (●) abundance estimates are shown, along with 95% CRIs.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information
The California large mesh drift gillnet fishery has been the only fishery known to interact with this stock. One Baird's beaked whale was incidentally killed in this fishery in 1994 (Julian and Beeson 1998), before acoustic pingers were first used in the fishery in 1996 (Barlow and Cameron 2003). Since 1996, no beaked whale of *any* species have been observed entangled or killed in this fishery (Carretta *et al.* 2008, Carretta *et al.* 2017a). Mean annual takes in Table 1 are based on 2011-2015 data. This results in an average estimated annual mortality of zero Baird's beaked whales (Carretta *et al.* 2017a). Gillnets have been documented to entangle marine mammals off Baja California (Sosa-Nishizaki *et al.* 1993), but no recent bycatch data from Mexico are available.

Table 1. Summary of available information on the incidental mortality and injury of Baird's beaked whales (California/Oregon/Washington Stock) in commercial fisheries that might take this species. The single observed entanglement resulted in the death of the animal. Coefficients of variation for mortality estimates are provided in parentheses. Mean annual takes are based on 2011-2015 data unless noted otherwise.

Fishery Name	Data Type	Year(s)	Percent Observer Coverage	Observed Mortality	Estimated Annual Mortality	Mean Annual Takes (CV in parentheses)
CA/OR thresher shark/swordfish drift gillnet fishery	observer data	2011 2012 2013 2014 2015	20% 19% 37% 24% 20%	0 0 0 0 0	0 0 0 0 0	0
Minimum total annual takes						0

Other mortality
California coastal whaling operations killed 15 Baird's beaked whales between 1956 and 1970, and 29 additional Baird's beaked whales were taken by whalers in British Columbian waters (Rice 1974). One

Baird's beaked whale stranded in Washington state in 2003 and the cause of death was attributed to a ship strike. No other human-caused mortality has been reported for this stock for the period 2011-2015 (Carretta *et al.* 2017b).

Anthropogenic sound sources, such as military sonar and seismic testing have been implicated in the mass strandings of beaked whales, including atypical events involving multiple beaked whale species (Simmonds and Lopez-Jurado 1991, Frantiz 1998, Anon. 2001, Jepson *et al.* 2003, Cox *et al.* 2006). While D'Amico *et al.* (2009) note that most mass strandings of beaked whales are unassociated with documented sonar activities, lethal or sub-lethal effects of such activities would rarely be documented, due to the remote nature of such activities and the low probability that an injured or dead beaked whale would strand. Filadelpho *et al.* (2009) reported statistically significant correlations between military sonar use and mass strandings of beaked whales in the Mediterranean and Caribbean Seas, but not in Japanese and Southern California waters, and hypothesized that regions with steep bathymetry adjacent to coastlines are more conducive to stranding events in the presence of sonar use. In Hawaiian waters, Faerber & Baird (2010) suggest that the probability of stranding is lower than in some other regions due to nearshore currents carrying animals away from beaches, and that stranded animals are less likely to be detected due to low human population density near many of Hawaii's beaches. Actual and simulated sonar are known to interrupt the foraging dives and echolocation activities of tagged beaked whales (Tyack *et al.* 2011). Blainville's beaked whale presence was monitored on hydrophone arrays before, during, and after sonar activities on a Caribbean military range, with evidence of avoidance behavior: whales were detected throughout the range prior to sonar exposure, not detected in the center of the range coincident with highest sonar use, and gradually returned to the range center after the cessation of sonar activity (Tyack *et al.* 2011). Fernández *et al.* (2013) report that there have been no mass strandings of beaked whales in the Canary Islands following a 2004 ban on sonar activities in that region. The absence of beaked whale bycatch in California drift gillnets following the introduction of acoustic pingers into the fishery implies additional sensitivity of beaked whales to anthropogenic sound (Carretta *et al.* 2008, Carretta and Barlow 2011).

STATUS OF STOCK

The status of Baird's beaked whales in California, Oregon and Washington waters relative to OSP is not known, and no abundance trend is evident (Moore and Barlow 2017). They are not listed as "threatened" or "endangered" under the Endangered Species Act nor designated as "depleted" under the MMPA. The average annual human-caused mortality during 2011-2015 is zero animals/year. Because recent fishery and human-caused mortality is less than the PBR (16), Baird's beaked whales are not classified as a "strategic" stock under the MMPA. Moore and Barlow (2017) estimated that there was a 72% probability that this population had a positive growth rate over the period 1991-2014. The total fishery mortality and serious injury for this stock is zero and can be considered to be insignificant and approaching zero. The impacts of anthropogenic sound on beaked whales remains a concern (Barlow and Gisiner 2006, Cox *et al.* 2006, Hildebrand *et al.* 2005, Weilgart 2007).

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MESOPLODONT BEAKED WHALES (*Mesoplodon* spp.):
California/Oregon/Washington Stocks

STOCK DEFINITION AND GEOGRAPHIC RANGE

Mesoplodont beaked whales are distributed throughout deep waters and along the continental slopes of the North Pacific Ocean. The six species known to occur in this region are: Blainville's beaked whale (*M. densirostris*), Perrin's beaked whale (*M. perrini*), Lesser beaked whale (*M. peruvianus*), Stejneger's beaked whale (*M. stejnegeri*), Gingko-toothed beaked whale (*M. gingkodens*), and Hubbs' beaked whale (*M. carlhubbsi*) (Mead 1989, Henshaw *et al.* 1997, Dalebout *et al.* 2002, MacLeod *et al.* 2006). Based on bycatch and stranding records in this region, it appears that Hubb's beaked whale is most commonly encountered (Carretta *et al.* 2008, Moore and Barlow 2013). Insufficient sighting records exist off the U.S. west coast (Figure 1) to determine any possible spatial or seasonal patterns in the distribution of mesoplodont beaked whales.

Until methods of distinguishing these six species at-sea are developed, the management unit must be defined to include all *Mesoplodon* stocks in this region. However, in the future, species-level management is desirable, and a high priority should be placed on finding means to obtain species-specific abundance information. For the Marine Mammal Protection Act (MMPA) stock assessment reports, three *Mesoplodon* stocks are defined: 1) all *Mesoplodon* species off California, Oregon and Washington (this report), 2) *M. stejnegeri* in Alaskan waters, and 3) *M. densirostris* in Hawaiian waters.

Figure 1. *Mesoplodon* beaked whale sightings based on shipboard surveys off California, Oregon and Washington, 1991-2014 . Key: ● = *Mesoplodon* spp.; ○ = identified *Mesoplodon densirostris*; ● = identified *Mesoplodon carlhubbsi*. Dashed line represents the U.S. EEZ, thin lines indicate completed transect effort of all surveys combined.

POPULATION SIZE

A trend-based analysis of line-transect data from surveys conducted between 1991 and 2014 provides new estimates of Mesoplodon species abundance (Moore and Barlow 2017). The new estimate accounts for the proportion of unidentified beaked whale sightings likely to be Mesoplodon beaked whales and uses a correction factor for missed animals adjusted to account for the fact that the proportion of animals on the trackline missed by observers increases in rough seas. The trend-model analysis incorporates information from the entire 1991- 2014 time series for each annual estimate of abundance, and suggests evidence of an increasing abundance trend over that time (Moore and Barlow 2017), which is a reversal of the population decline reported by Moore and Barlow 2013. The authors note caveats to this observation: sea surface temperatures in 2014 were extremely warm in the California Current, with many previously undetected (and rarely detected) subtropical and tropical species occurring in the study area (Cavole et al.
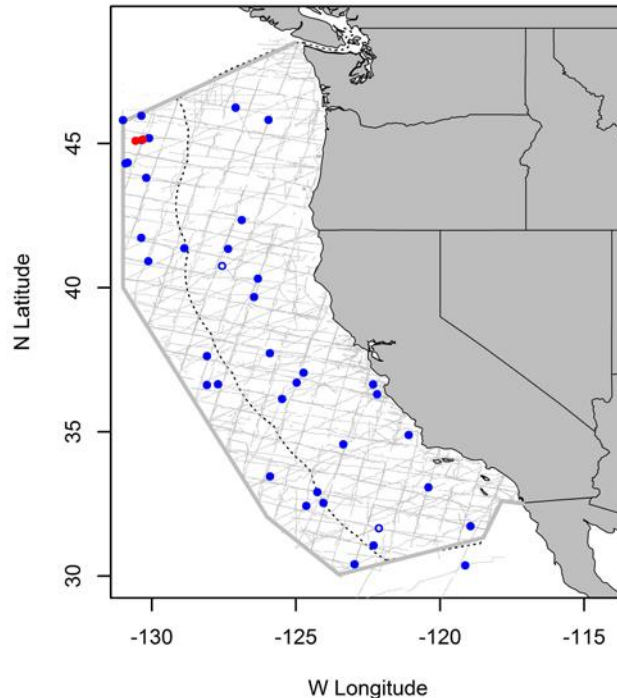
2016). They hypothesize that an influx of warm-water Mesoplodon species into the California Current may have contributed to the higher estimate for 2014. They also reiterate that very few temperate species of Mesoplodon have stranded in recent years, a piece of supporting evidence for the previously observed population decline (Moore and Barlow 2013). The best estimate of Mesoplodon abundance is represented by the model-averaged estimate for 2014 (Moore and Barlow 2017). Based on this analysis, the best (50th percentile) estimate of abundance for all species of Mesoplodon species combined in 2014 in waters off California, Oregon and Washington is 3,044 (CV=0.54).

Minimum Population Estimate

 The minimum population estimate (defined as the log-normal 20th percentile of the abundance estimate) for mesoplodont beaked whales in California, Oregon, and Washington is 1,967 animals.

Current Population Trend

 Moore and Barlow (2013) provided strong evidence, based on line-transect survey data and the historical stranding record off the U.S. west coast, that the abundance of *Mesoplodon* beaked whales declined in waters off California, Oregon and Washington between 1991 and 2008 (Moore and Barlow 2013,). This apparent trend is reversed with the additional analysis of data collected in 2014, which includes the highest estimate of *Mesoplodon* abundance in the 1991-2014 time series (Moore and Barlow 2017, Figure 2). Statistical analysis of line-transect survey data from 1991 - 2014 indicates a 0.87 probability of an increase during this period, with the mean long-term growth rate estimate from a Markov model of $r = 0.03$ (SD =

Figure 2. Abundance and trend estimates for mesoplodont beaked whales in the California Current, 1991-2014 (Moore and Barlow 2017). For each year, the Bayesian posterior median (●) is shown, along with 95% CRIs.

0.07), with 95% CRI ranging from −0.10 to +0.18, indicating high uncertainty in long-term dynamics. Patterns in the historical stranding record alone provide limited information about beaked whale abundance trends, but the stranding record appears generally consistent rather than at-odds with results of the line-transect survey analysis. Regional stranding networks along the Pacific coast of the U.S. and Canada originated during the 1980s, and beach coverage and reporting rates are thought to have increased throughout the 1990s and in to the early 2000s. Therefore, for a stable or increasing population, an overall increasing trend in stranding reports between the 1980s and 2000s would be expected. In contrast, reported strandings for *M. carlhubbsi* and *M. stejnegeri* in the California Current region have declined monotonically since the 1980s.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

 No information on current or maximum net productivity rates is available for mesoplodont beaked whales.

POTENTIAL BIOLOGICAL REMOVAL

 The potential biological removal (PBR) level for this stock is calculated as the minimum population size (1,967) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a species of unknown status with no known recent fishery mortality; Wade and Angliss 1997), resulting in a PBR of 20 mesoplodont beaked whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY
Fishery Information

The California large mesh drift gillnet fishery has been the only fishery historically known to interact with *Mesoplodon* beaked whales in this region. Between 1990 and 1995, a total of eight *Mesoplodon* beaked whales (5 Hubb's beaked whales (*Mesoplodon carlhubbsi*), one Stejneger's beaked whale (*Mesoplodon stejnegeri*), and two unidentified whales of the genus *Mesoplodon* were observed entangled in approximately 3,300 sets (Julian and Beeson 1998, Carretta *et al.* 2008, Carretta *et al.* 2017). Following the introduction of acoustic pingers into this fishery (Barlow and Cameron 2003), no beaked whales of any species have been observed entangled in over 5,400 observed sets (Carretta *et al.* 2008, Carretta *et al.* 2017). New model-based estimates of bycatch based on regression trees result in a very small estimate of bycatch with high uncertainty for a single species (*M. carlhubbsi*), for the most recent 5-year period, 2011-2015 (0.5 whales total, CV=2.3), despite zero entanglements observed during that time period (Carretta *et al.* 2017). This is due to the bycatch model incorporating all 26 years of observer data in the estimation process (Carretta *et al.* 2017). Estimates for *M. stejnegeri* and unidentified *Mesoplodon* species are zero for the same time period. Gillnets have been documented to entangle marine mammals off Baja California (Sosa-Nishizaki *et al.* 1993), but no recent bycatch data from Mexico are available.

Table 1. Summary of available information on the incidental mortality and injury of *Mesoplodon* beaked whales (California/Oregon/Washington Stocks) in commercial fisheries that might take these species.   Mean annual takes are based on 2011-2015 data unless noted otherwise.

Fishery Name	Data Type	Year	Percent Observer Coverage	Observed Mortality	Estimated Annual Mortality	Mean Annual Takes (CV in parentheses)
CA/OR thresher shark/swordfish drift gillnet fishery	observer	2011 2012 2013 2014 2015	20% 19% 37% 24% 20%	0 0 0 0 0	0 0 0 0 0	0 (unidentified *Mesoplodon* and *M. Stejnegeri* only)
		2011-2015	24%	0	*M. carlshubbsi* only 0.5 (2.3)	*M. carlshubbsi* only 0.1 (2.3)
Minimum total annual takes of all *Mesoplodon* beaked whales						0.1 (2.3)

Other mortality

Anthropogenic sound sources, such as military sonar and seismic testing have been implicated in the mass strandings of beaked whales, including atypical events involving multiple beaked whale species (Simmonds and Lopez-Jurado 1991, Frantiz 1998, Anon. 2001, Jepson *et al.* 2003, Cox *et al.* 2006). While D'Amico *et al.* (2009) note that most mass strandings of beaked whales are unassociated with documented sonar activities, lethal or sub-lethal effects of such activities would rarely be documented, due to the remote nature of such activities and the low probability that an injured or dead beaked whale would strand. Filadelpho *et al.* (2009) reported statistically significant correlations between military sonar use and mass strandings of beaked whales in the Mediterranean and Caribbean Seas, but not in Japanese and Southern California waters, and hypothesized that regions with steep bathymetry adjacent to coastlines are more conducive to stranding events in the presence of sonar use. In Hawaiian waters, Faerber and Baird (2010) suggest that the probability of stranding is lower than in some other regions due to nearshore currents carrying animals away from beaches, and that stranded animals are less likely to be detected due to low human population density near many of Hawaii's beaches.   Actual and simulated sonar are known to interrupt the foraging dives and echolocation activities of tagged beaked whales (Tyack *et al.* 2011, DeRuiter *et al.* 2013). Cuvier's beaked whales tagged and tracked during simulated mid-frequency sonar exposure showed avoidance reactions, including prolonged diving, cessation of echolocation click production associated with foraging, and directional travel away from the simulated sonar source (DeRuiter *et al.* 2013). Blainville's beaked whale presence was monitored on hydrophone arrays before, during, and after sonar activities on a Caribbean military range, with evidence of avoidance behavior: whales were detected throughout the range prior to sonar exposure, not detected in the center of the range coincident with highest sonar use, and

gradually returned to the range center after the cessation of sonar activity (Tyack *et al.* 2011). Fernández *et al.* (2013) report that there have been no mass strandings of beaked whales in the Canary Islands following a 2004 ban on sonar activities in that region. The absence of beaked whale bycatch in California drift gillnets following the introduction of acoustic pingers into the fishery implies additional sensitivity of beaked whales to anthropogenic sound (Carretta *et al.* 2008, Carretta and Barlow 2011).

STATUS OF STOCKS

The status of mesoplodont beaked whales in California, Oregon and Washington waters relative to OSP is not known, and the population decline previously reported by Moore and Barlow (2013) is no longer apparent with the addition of 2014 survey data, which includes the highest estimate of *Mesoplodon* abundance in the 1991-2014 time series (Moore and Barlow 2017). The probability of a population increase over the time period 1991-2014 was estimated as 0.87 by Moore and Barlow (2017), but this is confounded by the fact that most *Mesoplodon* sightings are not identified to species, and thus, which species are driving the observed increase are not known. The previously-reported decline in abundance by Moore and Barlow (2013) (trend-fitted 2008 abundance at approximately 30% of 1991 levels) and current uncertainty in the long-term growth rate of this genus in the region warrants further investigation. If the relatively high 2014 abundance estimate was due to a temporary influx of subtropical and tropical species into the region, the remaining temperate species may be below their carrying capacity and may be depleted, based on the previous findings of Moore and Barlow (2013). Assessing changes in abundance for any species may also be confounded by distributional shifts within the California Current related to ocean-warming (Cavole *et al.* 2015). The average annual known human-caused fishery mortality between 2011 and 2015 is zero for *M. stejnegeri* and unidentified *Mesoplodon*. A negligible estimate of drift gillnet bycatch (0.1 whales annually) is predicted for *M. carlshubbsi* over the same time period, despite zero observations of entanglements in the fishery since 1994 (Carretta *et al.* 2017). None of the six species is listed as "threatened" or "endangered" under the Endangered Species Act and given the relative lack of bycatch in gillnet fisheries in this region, these stocks are considered non-strategic. It is likely that the difficulty in identifying these animals in the field will remain a critical obstacle to obtaining species-specific abundance estimates and stock assessments in the future. The impacts of anthropogenic sound on beaked whales remains a concern (Barlow and Gisiner 2006, Cox *et al.* 2006, Hildebrand *et al.* 2005, Weilgart 2007).

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CUVIER'S BEAKED WHALE (*Ziphius cavirostris*): California/Oregon/Washington Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Cuvier's beaked whales are distributed widely throughout deep waters of all oceans (MacLeod *et al.* 2006). Off the U.S. west coast, this species is the most commonly encountered beaked whale (Figure 1). No seasonal changes in distribution are apparent from stranding records, and morphological evidence is consistent with the existence of a single eastern North Pacific population from Alaska to Baja California, Mexico (Mitchell 1968). For the Marine Mammal Protection Act (MMPA) stock assessment reports, Cuvier's beaked whales within the Pacific U.S. Exclusive Economic Zone are divided into three discrete, non-contiguous areas: 1) waters off California, Oregon and Washington (this report), 2) Alaskan waters, and 3) Hawaiian waters.

POPULATION SIZE

Although Cuvier's beaked whales have been sighted along the U.S. west coast on several line transect surveys utilizing both aerial and shipboard platforms, the rarity of sightings has historically precluded reliable population estimates. Early abundance estimates were imprecise and negatively-biased by an unknown amount because of the large proportion of time this species spends submerged, and because ship surveys before 1996 covered only California waters, and thus did not include animals off Oregon/Washington.

Figure 1. Cuvier's beaked whale sightings based on shipboard surveys off California, Oregon and Washington, 1991-2014 Dashed line represents the U.S. EEZ, thin lines indicate completed transect effort of all surveys combined.

Furthermore, survey data include a large number of unidentified beaked whale sightings that are probably either *Mesoplodon* sp. or Cuvier's beaked whales (*Ziphius cavirostris*). A line-transect survey of U.S. west coast waters in 2014 yielded an abundance estimate of 3,775 (CV=0.68) Cuvier's beaked whales (Barlow 2016). The same analysis also provided estimates for previous years dating back to 1991, but did not evaluate trends in abundance. A trend-based analysis of line-transect data from surveys conducted between 1991 and 2014 provides new estimates of Cuvier's beaked whale abundance (Moore and Barlow 2017). The trend-model analysis incorporates information from the entire 1991-2014 time series for each annual estimate of abundance, and given the strong evidence of a decreasing abundance trend over that time (Moore and Barlow 2013, 2017), the best estimate of abundance is represented by the model-averaged estimate for 2014. Based on this analysis, the best (50th percentile) estimate of abundance for Cuvier's beaked whales in 2014 in waters off California, Oregon and Washington is 3,274 (CV= 0.67) whales, which is similar to the line-transect estimate of 3,775 (CV=0.68) whales in 2014 estimated by Barlow (2016). The lower estimates of Cuvier's beaked whale abundance provided by Moore and Barlow (2017) compared with the Moore and Barlow
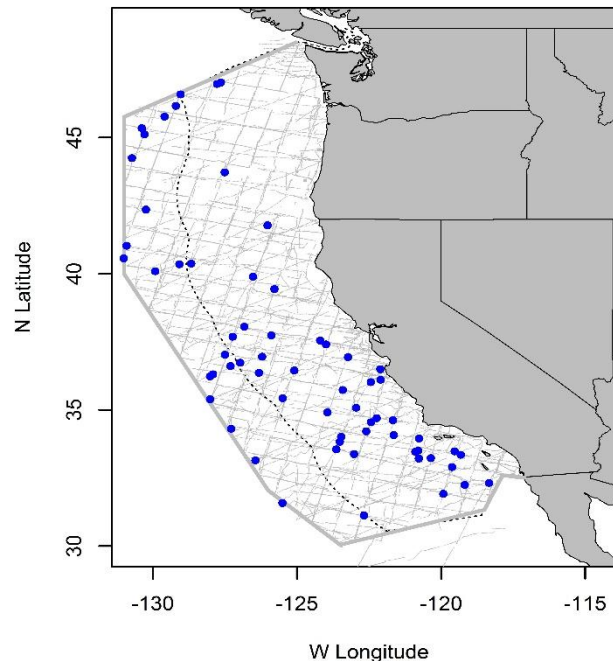
(2013) estimates are due to a higher trackline detection probability (*g(0)*) value, based on new Beaufort sea state-specific *g(0)* analysis published by Barlow (2015).

Minimum Population Estimate

Based on the analysis by Moore and Barlow (2017), the minimum population estimate (defined as the log-normal 20th percentile of the abundance estimate) for Cuvier's beaked whales in California, Oregon, and Washington is 2,059 animals.

Current Population Trend

There is substantial evidence, based on line-transect survey data and the historical stranding record off the U.S. west coast, that the abundance of Cuvier's beaked whales in waters off California, Oregon and Washington is lower than in the early 1990s (Moore and Barlow 2013, 2017, Figure 2). Statistical analysis of line-transect survey data from 1991 - 2014 indicates a 0.85 probability of decline during this period (Moore and Barlow 2017), with the mean annual rate of population change estimated to have been − 3.0% per year (95% CRI: -10% to +3%, regression model results), although abundance throughout the 2000s appears fairly stable. Patterns in the historical stranding record alone provide
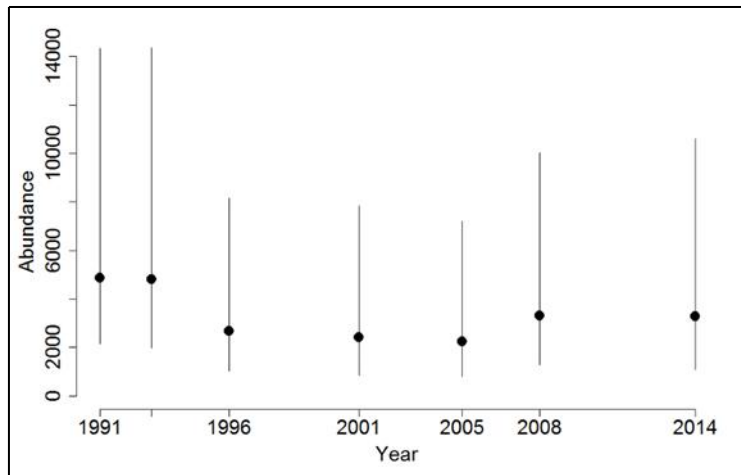
Figure 2. Abundance estimates for Cuvier's beaked whales in the California Current, 1991-2014 (Moore and Barlow 2017). For each year, the Bayesian posterior median (●) abundance estimates are shown, along with 95% CRIs.

limited information about beaked whale abundance trends, but the stranding record appears generally consistent rather than at-odds with results of the line-transect survey analysis. Regional stranding networks along the Pacific coast of the U.S. and Canada originated during the 1980s, and beach coverage and reporting rates are thought to have increased throughout the 1990s and in to the early 2000s. Therefore, for a stable or increasing population, an overall increasing trend in stranding reports between the 1980s and 2000s would be expected. Patterns of Cuvier's beaked whale strandings data are highly variable across stranding network regions, but an overall increasing trend from the 1980s through 2000s is not evident within the California Current area, contrary to patterns for Baird's beaked whales (Moore and Barlow 2013) and for cetaceans in general (e.g., Norman *et al.* 2004, Danil *et al.* 2010).

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No information on current or maximum net productivity rates is available for this species.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (2,059) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a species of unknown status with no known fishery mortality; Wade and Angliss 1997), resulting in a PBR of   21 Cuvier's beaked whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY
Fishery Information

The California swordfish drift gillnet fishery has been the only fishery historically known to interact with this stock. Prior to the introduction of acoustic pingers into the fishery in 1996, there were 21 Cuvier's beaked whales observed entangled in approximately 3,300 drift gillnet fishery sets: 1992 (six animals), 1993 (three), 1994 (six) and 1995 (six) (Julian and Beeson 1998). Since acoustic pinger use, no Cuvier's beaked

whales have been observed entangled in over 5,400 observed fishing sets (Barlow and Cameron 2003, Carretta *et al.* 2008, Carretta and Barlow 2011, Carretta *et al.* 2017). New model-based estimates of bycatch based on regression trees identify the use of acoustic pingers and longitude as two variables influencing the bycatch of Cuvier's beaked whales in the fishery (Carretta *et al.* 2017). Mean annual takes in Table 1 are based only on 2011-2015 data. Although no Cuvier's beaked whales were observed entangled in the most recent 5-year time period, bycatch models produced a negligible estimate of bycatch for this 5-year period of 0.1 (CV=2.8) whales. This results in an average estimated annual mortality of 0.02 (CV=2.8) Cuvier's beaked whales.

Table 1. Summary of available information on the incidental mortality and serious injury of Cuvier's beaked whales (California/ Oregon/Washington Stock) in commercial fisheries that might take this species. Mean annual takes are based on 2011-2015 data unless noted otherwise.

Fishery Name	Data Type	Year(s)	Percent Observer Coverage	Observed Mortality + ReleasedAlive	Estimated Annual Mortality / Mortality + Entanglements	Mean Annual Takes (CV in parentheses)
CA/OR thresher shark/swordfish drift gillnet fishery	observer data	2011 2012 2013 2014 2015	20% 19% 37% 24% 20%	0 0 0 0 0		
		2011-2015	**24%**	**0**	**0.1 (2.8)**	**0.02 (2.8)**
Minimum total annual takes						0.02 (2.8)

Gillnets have been documented to entangle marine mammals off Baja California (Sosa-Nishizaki *et al.* 1993), but no recent bycatch data from Mexico are available.

Other mortality

Anthropogenic sound sources, such as military sonar and seismic testing have been implicated in the mass strandings of beaked whales, including atypical events involving multiple beaked whale species (Simmonds and Lopez-Jurado 1991, Frantiz 1998, Anon. 2001, Jepson *et al.* 2003, Cox *et al.* 2006). While D'Amico *et al.* (2009) note that most mass strandings of beaked whales are unassociated with documented sonar activities, lethal or sub-lethal effects of such activities would rarely be documented, due to the remote nature of such activities and the low probability that an injured or dead beaked whale would strand. Filadelpho *et al.* (2009) reported statistically significant correlations between military sonar use and mass strandings of beaked whales in the Mediterranean and Caribbean Seas, but not in Japanese and Southern California waters, and hypothesized that regions with steep bathymetry adjacent to coastlines are more conducive to stranding events in the presence of sonar use. In Hawaiian waters, Faerber & Baird (2010) suggest that the probability of stranding is lower than in some other regions due to nearshore currents carrying animals away from beaches, and that stranded animals are less likely to be detected due to low human population density near many of Hawaii's beaches. Actual and simulated sonar are known to interrupt the foraging dives and echolocation activities of tagged beaked whales (Tyack *et al.* 2011, DeRuiter *et al.* 2013). Cuvier's beaked whales tagged and tracked during simulated mid-frequency sonar exposure showed avoidance reactions, including prolonged diving, cessation of echolocation click production associated with foraging, and directional travel away from the simulated sonar source (DeRuiter *et al.* 2013). Blainville's beaked whale presence was monitored on hydrophone arrays before, during, and after sonar activities on a Caribbean military range, with evidence of avoidance behavior: whales were detected throughout the range prior to sonar exposure, not detected in the center of the range coincident with highest sonar use, and gradually returned to the range center after the cessation of sonar activity (Tyack *et al.* 2011). Fernández *et al.* (2013) report that there have been no mass strandings of beaked whales in the Canary Islands following a 2004 ban on sonar activities in that region. The absence of beaked whale bycatch in California drift gillnets following the introduction of acoustic pingers into the fishery implies additional sensitivity of beaked whales to anthropogenic sound (Carretta *et al.* 2008, Carretta and Barlow 2011).

STATUS OF STOCK

The status of Cuvier's beaked whales in California, Oregon and Washington waters relative to OSP is not known, but Moore and Barlow (2013) indicated a substantial likelihood of population decline in the California Current since the early 1990s, at a mean rate of -2.9% per year, which corresponds to trend-fitted abundance levels in 2008 (most recent survey) being at 61% of 1991 levels.   New trend estimates also indicate evidence of a population decline between 1990 and 2014, with an 85% probability of a decline at a mean rate of -3.0% per year (Moore and Barlow 2017). Cuvier's beaked whales are not listed as "threatened" or "endangered" under the Endangered Species Act, nor designated as "depleted" under the MMPA. However, the long-term decline in Cuvier's beaked whale abundance in the California Current reported by Moore and Barlow (2013, 2017), and the degree of decline (trend-fitted 2014 abundance at approximately 67% of 1991 levels) suggest that this stock may be below its carrying capacity. Assessing changes in abundance for any species may also be confounded by distributional shifts within the California Current related to ocean-warming (Cavole *et al.* 2015). .   Given that the stock is not currently ESA listed or designated as depleted, and human-caused mortality is below PBR, it is not strategic. Moore and Barlow (2013) ruled out bycatch as a cause of the decline in Cuvier's beaked whale abundance and suggest that impacts from anthropogenic sounds such as naval sonar and deepwater ecosystem changes within the California Current are plausible hypotheses warranting further investigation. The average annual known human-caused mortality between 2011 and 2015 is negligible (0.02 whales annually in the drift gillnet fishery) and reflects a small probability that true bycatch in this fishery may be greater than the zero observed from approximately 5,400 fishing sets since 1996 (Carretta *et al.* 2017).   The total fishery mortality and serious injury for this stock is less than 10% of the PBR and thus is considered to be insignificant and approaching zero. The impacts of anthropogenic sound on beaked whales remains a concern (Barlow and Gisiner 2006, Cox *et al.* 2006, Hildebrand *et al.* 2005, Weilgart 2007).

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SPERM WHALE (*Physeter macrocephalus*):
California/Oregon/Washington Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Sperm whales are distributed across the entire North Pacific and into the southern Bering Sea in summer, but the majority are thought to be south of 40ºN in winter (Rice 1974; Rice 1989; Gosho *et al.* 1984; Miyashita *et al.* 1995). The International Whaling Commission (IWC) historically divided the North Pacific into two management regions (Donovan 1991) defined by a zig-zag line which starts at 150ºW at the equator, is 160ºW between 40-50ºN, and ends up at 180ºW north of 50ºN; however, the IWC has not reviewed this stock boundary recently (Donovan 1991). Sperm whales are found year-round in California waters (Dohl *et al.* 1983; Barlow 1995; Forney *et al.* 1995), but they reach peak abundance from April through mid-June and from the end of August through mid-November (Rice 1974). Sperm whales are seen off Washington and Oregon in every season except winter (Green *et al.* 1992). Of 176 sperm whales that were marked with Discovery tags off southern California in winter 1962-70, only three were recovered by whalers: one off northern California in June, one off Washington in June, and another far off British Columbia in April (Rice 1974). Recent summer/fall surveys in the eastern tropical Pacific (Wade and Gerrodette 1993) show that although

Figure 1. Sperm whale sighting locations from shipboard surveys off California, Oregon, and Washington, 1991-2014. Dashed line represents the U.S. EEZ, thin lines indicate completed transect effort of all surveys combined.

sperm whales are widely distributed in the tropics, their relative abundance declines westward towards the middle of the tropical Pacific (near the IWC stock boundary at 150ºW) and declines northward towards the tip of Baja California. Sperm whale population structure in the eastern tropical Pacific is unknown, but the only photographic matches of known individuals from this area have been between the Galapagos Islands and coastal waters of South America (Dufault and Whitehead 1995) and between the Galapagos Islands and the southern Gulf of California (Jaquet *et al.* 2003), suggesting that eastern tropical Pacific animals constitute a distinct stock. No apparent distributional hiatus was found between the U.S. EEZ off California and Hawaii during a survey designed specifically to investigate stock structure and abundance of sperm whales in the northeastern temperate Pacific (Barlow and Taylor 2005). Sperm whales in the California Current have been identified as demographically independent from animals in Hawaii and the Eastern Tropical Pacific, based on genetic analyses of single-nucleotide polymorphisms (SNPs), microsatellites, and mtDNA (Mesnick *et al.* 2011). For the Marine Mammal Protection Act (MMPA) stock assessment reports, sperm whales within the Pacific U.S. EEZ are divided into three discrete, non-contiguous areas: 1) California, Oregon and Washington waters (this report), 2) waters around Hawaii, and 3) Alaska waters.
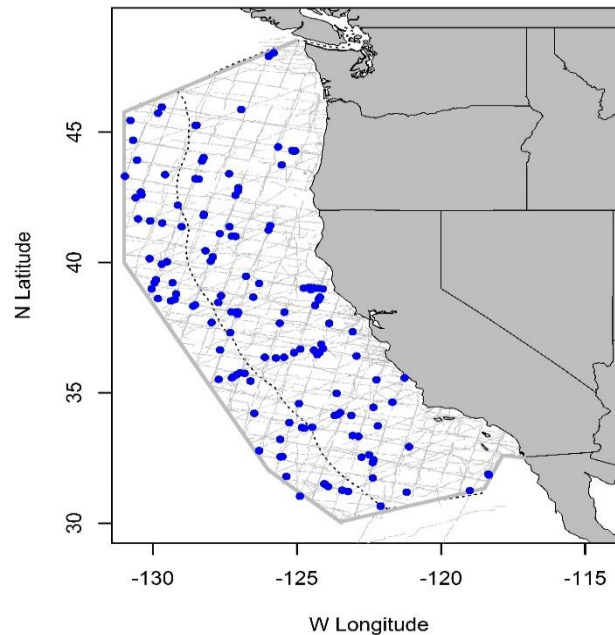
POPULATION SIZE

Previous estimates of sperm whale abundance from 2005 (3,140, CV=0.40, Forney 2007) and 2008 (300, CV=0.51, Barlow 2010) show a ten-fold difference that cannot be attributed to human-caused or natural population declines and likely reflect sampling variance or inter-annual variability in movement of animals into and out of the study area. New estimates of sperm whale abundance in California, Oregon, and Washington waters out to 300 nmi are available from a trend-model analysis of line-transect data collected from seven surveys conducted from 1991 to 2014 (Moore and Barlow 2017), using the same methods and in a previous abundance trend analysis (Moore and Barlow 2014). Abundance trend models incorporate information from the entire 1991-2014 time series to obtain each annual abundance estimate, yielding estimates with less inter-annual variability. The trend model also uses improved estimates of group size and trackline detection probability (Moore and Barlow 2014, Barlow 2015). Sperm whale abundance estimates based on the trend-model ranged between 2,000 and 3,000 animals for the 1991-2014 time series (Moore and Barlow 2014). The best estimate of sperm whale abundance in the California Current is the trend-based estimate corresponding to the most recent survey (2014), or 1,997 (CV= 0.57) animals. This estimate is corrected for diving animals not seen during surveys.

Minimum Population Estimate

The minimum population estimate for sperm whales is taken as the lower 20th percentile of the posterior distribution of the 2014 abundance estimate, or 1,270 whales (Moore and Barlow 2017).

Current Population Trend

Moore and Barlow (2014) reported that sperm whale abundance appeared stable from 1991 to 2008 (Figure 2) and additional data from a 2014 survey does not change that conclusion (Moore and Barlow 2017). Estimated growth rates of the population include a high level of uncertainty, with a growth rate parameter from a Markov model having a posterior median and mean of +0.01 (SD = 0.06) with a broad 95% credible interval (CRI) ranging from -0.11 to +0.13 and a 60% chance of being positive. Another growth rate estimate a regression model had a posterior mean of +0.01 with 95% CRI ranging from −0.06 to +0.07 (62% chance that growth has been positive), indicating that for the 1991 – 2014 study period, conclusions about whether the population has increased or decreased are uncertain (Moore and Barlow 2017).

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

A reliable estimate of the maximum net productivity rate is not currently available for the CA/OR/WA stock of sperm whales. Hence, until additional data become available, it is recommended that the cetacean maximum net productivity rate (R_{max}) of 4% be employed for this stock at this time (Wade and Angliss 1997).

Figure 2. Trend-based estimates of sperm whale abundance in the California Current, 1991-2014 (Moore and Barlow 2017). Abundance estimates (posterior medians [●] and 95% CRIs) from the trend model.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (1,270) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.1 (for an endangered stock with N_{min} <1,500; Taylor *et al.* 2003), resulting in a PBR of 2.5 animals per year.
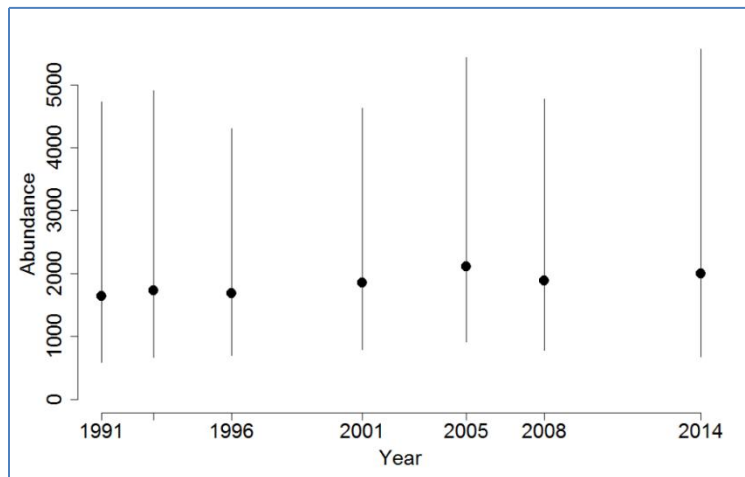
HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Serious Injury Guidelines

NMFS uses guidance from previous serious injury workshops, expert opinion, and analysis of historic injury cases to distinguish serious from non-serious injury (Angliss and DeMaster 1998, Andersen *et al.* 2008, NOAA 2012). NMFS defines serious injury as an "injury that is more likely than not to result in mortality."

Fishery Information

The fishery most likely to directly take sperm whales from this stock is the California thresher shark/swordfish drift gillnet fishery (Julian and Beeson 1998, Carretta *et al.* 2017a, 2017b). Observed serious injury and mortality has been rarely documented in the gillnet fishery (10 animals from 6 events observed during 8,711 fishing sets between 1990 and 2015, Carretta *et al.* 2017b). Previous ratio estimates of drift gillnet bycatch for this stock suffered from inter-annual volatility and estimation bias because estimates were based on intra-annual data where observed entanglements were rare and observer coverage was low (Julian and Beeson 1998, Carretta *et al.* 2004, Carretta and Moore, 2014, Carretta *et al.* 2017b). The prescribed strategy of pooling 5 years of annual bycatch estimates in stock assessments (Wade and Angliss 1997) is insufficient to overcome these biases when events are rare and estimates are based on within-year data (Carretta and Moore 2014). However, model-based bycatch estimates that incorporate all available data for annual estimates allow for the robust pooling of data over 5-year time periods. New model-based estimates of sperm whale bycatch based on random forest regression trees were generated for the 26-year period 1990-2015, where annual estimates incorporate data from all years (Carretta *et al.* 2017b). Additionally, estimates were derived for the most recent 5-year period of 2011-2015, and because the last observation of sperm whale entanglement occurred >5 years ago, Table 1 also includes bycatch estimates for the most recent 10-year period (2006-2015) for additional context. Estimated entanglements for the period 2011-2015 in the California drift gillnet fishery are 2.6 (CV=1.2) sperm whales, however, not all of these represent deaths or serious injuries (Carretta *et al.* 2017b). Based on a review of sperm whale entanglements in the fishery, 7 of the 10 entanglements resulted in serious injury (n=2) or death (n=5), with the remaining 3 cases resulting in non-serious injuries because animals were released from nets uninjured and were expected to live. The estimated number of sperm whales seriously-injured or killed from 2011-2015 is therefore 1.8 (CV=1.3) whales (Carretta *et al.* 2017b), or 0.4 whales annually (Table 1). The 5-year annual mean (0.4 whales, CV=1.3) is similar to the 10-year annual mean of 0.55 (CV=0.78) whales (Table 1). Two notable differences between intra-annual ratio estimates and model-based estimates of bycatch are: 1) annual model-based estimates can be positive, even when no entanglements were observed and 2) estimates can take on fractional values (<1 whale) (Carretta *et al.* 2017b, Table 1). As some estimates of serious injury and mortality are < 0.5 of a whale, resulting coefficients of variation (CVs) can be quite large due to the extremely small mean estimates. Of particular note is that the regression tree bycatch estimate for 2010 is 2.0 sperm whales (rounded value of 2 observations plus an estimated 0.03 whales from unobserved sets) (Carretta *et al.* 2017b). The ratio estimate of bycatch for the same year is 16.7 whales and is considered positively-biased (Carretta *et al.* 2017b).

Strandings of sperm whales are rare and it is expected that documented anthropogenic deaths and injuries due to entanglements within unknown fisheries or ingestion of marine debris represent a small fraction of the true number of cases, due to the low probability that the carcass of a highly-pelagic species washes ashore (Williams *et al.* 2011, Carretta *et al.* 2016a). Published summaries of human-caused mortality and serious injury of sperm whales from unidentified fisheries and marine debris on the U.S. west coast include records inclusive from 2007 to 2015 (Jacobsen *et al.* 2010, Carretta *et al.* 2013, 2014, 2015, 2016b, 2017a). Three separate sperm whale strandings in 2008 (all dead animals) showed evidence of fishery interactions (Jacobsen *et al.* 2010). Two whales died from gastric impaction as a result of ingesting multiple types of floating polyethylene netting (Jacobsen *et al.* 2010). The variability in size and age of the ingested net material suggests that it was ingested as surface debris and was not the result of fishery depredation (Jacobsen *et al.* 2010). Net types recovered from the whales' stomachs included portions of gillnet, bait nets, and fish/shrimp trawl nets. A third whale in 2008 showed evidence of entanglement scars (Carretta *et al.* 2013). The mean annual serious injury and mortality of sperm whales due to unidentified fisheries for 2007-2015 is 3 animals / 9 years, or 0.3 whales annually. Total annual fishery-related serious injury and mortality of sperm whales is the sum of California drift gillnet fishery (0.4/yr), plus unidentified fisheries (≥0.3 / yr), or 0.7 whales annually (Table 1).

Table 1. Summary of available information on the incidental mortality and injury of sperm whales (CA/OR/WA stock) for commercial fisheries that might take this species. n/a indicates that data are not available. Mean annual serious injury and mortality for the California swordfish drift gillnet fishery are based on 2011-2015 data and annual estimates for the most recent 10-year period are provided for additional context. The

Fishery Name	Year(s)	Data Type	Percent Observer Coverage	Observed mortality (and serious injury in parentheses)	Estimated mortality and serious injury (CV in parentheses)	Mean annual mortality and serious injury (CV in parentheses)
CA thresher shark/swordfish drift gillnet fishery	2006	observer	19%	0	0.6 (3.4)	0.55 (0.78)
	2007		16%	0	0.9 (2.4)	
	2008		14%	0	0.1 (4.2)	
	2009		13%	0	0.1 (3.6)	
	2010		12%	1 (1)	2 (n/a)	
	2011		20%	0	0.4 (3.7)	
	2012		19%	0	0.2 (2.8)	
	2013		37%	0	0.2 (2.3)	
	2014		24%	0	0.9 (1.9)	
	2015		20%	0	0.1 (6.8)	
	2011-2015	**observer**	**24%**	**0**	**1.8 (1.3)**	**0.4 (1.3)**
Unknown fishery	2007-2015	stranding	n/a	3	≥ 3	≥ 0.33 (n/a)
Total annual takes						≥ 0.7 (1.3)

Sperm whales from the North Pacific stock are known to depredate on longline sablefish catch in the Gulf of Alaska and sometimes incur serious injuries from becoming entangled in gear (Sigler *et al.* 2008, Allen and Angliss 2011). An unknown number of whales from the CA/OR/WA stock probably venture into waters where Alaska longline fisheries operate, but the amount of temporal and spatial overlap is unknown. Thus, the risk of serious injury to CA/OR/WA stock sperm whales resulting from longline fisheries cannot be quantified.

Ship Strikes

One sperm whale died as the result of a ship strike in Oregon in 2007 (NMFS Northwest Regional Stranding data, unpublished). Another sperm whale was struck by a 58-foot sablefish longline vessel in 2007 while at idle speed (Jannot *et al.* 2011). The observer noted no apparent injuries to the whale. Based on the size and speed of the vessel relative to the size of a sperm whale, this incident was categorized as a non-serious injury (Carretta *et al.* 2013). For the most recent 5-year period of 2011-2015, one ship strike death of a sperm whale was documented in 2012 (Carretta *et al.* 2017a) and the mean annual average mortality and serious injury is ≥ 0.2 whales. Due to the low probability of a sperm whale carcass washing ashore, estimated ship strike deaths are likely underestimated. Ship strikes are assessed over the most recent 5-year period to reflect the degree of shipping risk to large whales since ship traffic routes changed in response to new ship pollution rules implemented in 2009 (McKenna *et al.* 2012, Redfern *et al.* 2013).

STATUS OF STOCK

The only estimate of the status of North Pacific sperm whales in relation to carrying capacity (Gosho *et al.* 1984) is based on a CPUE method which is no longer accepted as valid. Whaling removed at least 436,000 sperm whales from the North Pacific between 1800 and the end of legal commercial whaling for this species in 1987 (Best 1976; Ohsumi 1980; Brownell 1998; Kasuya 1998). Of this total, an estimated 33,842 were taken by Soviet and Japanese pelagic whaling operations in the eastern North Pacific from the longitude of Hawaii to the U.S. West coast, between 1961 and 1976 (Allen 1980), and approximately 1,000 were reported taken in land-based U.S. West coast whaling operations between 1919 and 1971 (Ohsumi 1980;

Clapham *et al.* 1997). There has been a prohibition on taking sperm whales in the North Pacific since 1988, but large-scale pelagic whaling stopped in 1980. Sperm whales are formally listed as "endangered" under the Endangered Species Act (ESA), and consequently the California to Washington stock is automatically considered as a "depleted" and "strategic" stock under the MMPA. The status of sperm whales with respect to carrying capacity and optimum sustainable population (OSP) is unknown. Including annual fishery ($\geq$ 0.7) and ship-strike (≥ 0.2) mortality and serious injury, the annual rate of documented mortality and serious injury (≥ 0.9 per year) is less than the calculated PBR (2.5) for this stock, but this is likely underestimated due to incomplete detection of carcasses. Total human-caused mortality is greater than 10% of the calculated PBR and, therefore, cannot be considered to be insignificant and approaching zero mortality and serious injury rate. Increasing levels of anthropogenic sound in the world's oceans has been suggested to be a habitat concern for whales, particularly for deep-diving whales like sperm whales that feed in the ocean's "sound channel".

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HUMPBACK WHALE (*Megaptera novaeangliae*):
California/Oregon/Washington Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

NMFS has conducted a global Status Review of humpback whales (Bettridge *et al*. 2015), and recently revised the ESA listing of the species (81 FR 62259, September 8, 2016). NMFS is evaluating the stock structure of humpback whales under the MMPA, but no changes to current stock structure are presented at this time. However, effects of the ESA listing final rule on the status of the stock are discussed below.

Northern Hemisphere humpback whales (*M. novaeangliae kuzira*) comprise a distinct subspecies based on mtDNA and DNA relationships and distribution compared to North Atlantic humpback whales (*M n. novaeangliae*) and those in the Southern Hemisphere (*M. n. australis*) (Jackson *et al*. 2014). Humpback whales occur throughout the North Pacific, with multiple populations currently recognized based on low-latitude winter breeding areas (Baker *et al*. 1998, Calambokidis *et al*. 2001, Calambokidis *et al*. 2008, Barlow *et al*. 2011, Fleming and Jackson 2011). North Pacific breeding areas fall broadly into three regions, including the 1) western Pacific (Japan and Philippines); 2) central Pacific (Hawaiian Islands); and 3) eastern Pacific (Central America and Mexico) (Calambokidis *et al*. 2008). Exchange of animals between breeding areas rarely occurs, based on photo-identification data of individual whales (Calambokidis *et al*. 2001, Calambokidis *et al*.

Figure 1. Humpback whale sightings based on shipboard surveys off California, Oregon, and Washington, 1991-2014. Dashed line represents the U.S. EEZ, thin lines indicate completed transect effort of all surveys combined. See Appendix 2 for data sources and information on timing and location of survey effort.

2008). Photo-identification evidence also suggests strong site fidelity to feeding areas, but animals from multiple feeding areas converge on common winter breeding areas (Calambokidis *et al*. 2008). Baker *et al*. (2008) reported significant differences in mtDNA haplotype frequencies among different breeding and feeding areas in the North Pacific, reflecting strong matrilineal site fidelity to the respective migratory destinations. The most significant differences in haplotype frequencies were found between the California/Oregon feeding area and Russian and Southeastern Alaska feeding areas (Baker *et al*. 2008). Among breeding areas, the greatest level of differentiation was found between Okinawa and Central America and most other breeding grounds (Baker *et al*. 2008). Genetic differences between feeding and breeding grounds were also found, even for areas where regular exchange of animals between feeding and breeding grounds is confirmed by photo-identification (Baker *et al*. 2008).

Along the U.S. west coast, one stock is currently recognized, including two separate feeding groups: 1) a California and Oregon feeding group of whales that belong to the Central American and Mexican distinct population segments (DPSs) defined under the ESA (81 FR 62259, September 8, 2016), 2) a northern Washington and southern British Columbia feeding group that primarily includes whales from the Mexican DPS but also includes a small number of whales from the Hawaii and Central American DPSs (Calambokidis *et al*. 2008, Barlow *et al*. 2011, Wade *et al*. 2016). Very few photographic matches between these feeding groups have been documented (Calambokidis *et al*. 2008). Seven 'biologically important areas' for humpback whale feeding are identified off the U.S. west coast by Calambokidis *et al*. (2015), including five in California, one in Oregon, and one in Washington.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, the California/Oregon/Washington Stock is defined to include humpback whales that feed off the west coast of the
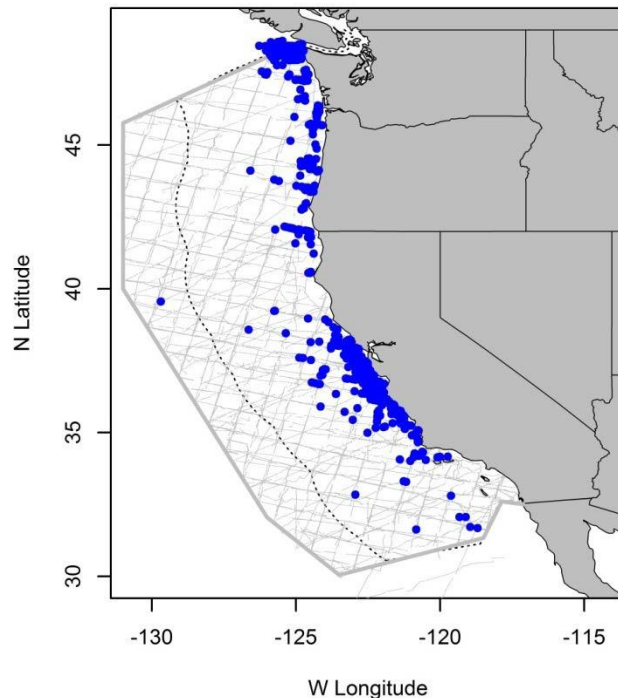
United States, including animals from both the California-Oregon and Washington-southern British Columbia feeding groups (Calambokidis *et al*. 1996, Calambokidis *et al*. 2008, Barlow *et al*. 2011). Three other stocks are recognized in the U.S. MMPA Pacific stock assessment reports: the Central North Pacific Stock (with feeding areas from Southeast Alaska to the Alaska Peninsula), the Western North Pacific Stock (with feeding areas from the Aleutian Islands, the Bering Sea, and Russia), and the American Samoa Stock in the South Pacific (with largely undocumented feeding areas as far south as the Antarctic Peninsula).

POPULATION SIZE

Based on whaling statistics, the pre-1905 population of humpback whales in the North Pacific was estimated to be 15,000 (Rice 1978), but this population was reduced by whaling to approximately 1,200 by 1966 (Johnson and Wolman 1984). A photo-identification study in 2004-2006 estimated the abundance of humpback whales in the entire Pacific Basin to be 21,808 (CV=0.04) (Barlow *et al*. 2011). Barlow (2016) recently estimated 3,064 (CV= 0.82) humpback whales from a 2014 summer/fall ship line-transect survey of California, Oregon, and Washington waters. Abundance estimates from photographic mark-recapture surveys conducted in California and Oregon waters every year from 1991 through 2011 represent the most precise estimates (Calambokidis 2013). These estimates include only animals photographed in California and Oregon waters and not animals that are part of the separate feeding group found off Washington state and southern British Columbia (Calambokidis *et al*. 2009). California and Oregon estimates range from approximately 1,100 to 2,600 animals, depending on the choice of recapture model and sampling period (Figure 2). The best estimate of abundance for California and Oregon waters is taken as the 2008-2011 Darroch estimate of 1,729 (CV = 0.03) whales, which is also the most precise estimate (Calambokidis and Barlow 2013). This estimate includes virtually the entire Central American DPS, which was recently estimated to include 411 (CV=0.3) whales based on 2004-2006 photographic mark-recapture data (Wade *et al*. 2016).

Calambokidis *et al*. (2008) reported a range of photographic mark-recapture abundance estimates (145 – 469) for the northern Washington and southern British Columbia feeding group most recently in 2005. The best model estimate from that paper (lowest AIC$_c$ score) was reported as 189 (CV not reported) animals. This estimate is more than 8 years old and is outdated for use in stock assessments; however, because west-coast humpback whale populations are growing (Calambokidis and Barlow 2013), this is still a valid minimum population estimate.

Combining abundance estimates from both the California/Oregon and Washington/southern British Columbia feeding groups (1,729 + 189) yields an estimate of 1,918 (CV ≈ 0.03) animals for the California/Oregon/Washington stock. The approximate CV of 0.03 for the combined estimate reflects that a vast majority of the variance is derived from the California and Oregon estimate (CV=0.03) and that no CV was provided for the Washington state and southern British Columbia estimate.

Minimum Population Estimate

The minimum population estimate for humpback whales in the California/Oregon/Washington stock is taken as the lower 20th percentile of the log-normal distribution of the combined mark-recapture estimate for both feeding groups given above, or 1,876 animals.

Current Population Trend

Ship surveys provide some indication that humpback whales increased in abundance in California coastal waters between 1979/80 and 1991 (Barlow 1994) and between 1991 and 2014 (Barlow 2016), but this increase was not steady, and estimates showed slight dips in 2001 and 2008. Mark-recapture population estimates had shown a long-term increase of approximately 8% per year (Calambokidis *et al*. 2009, Figure 2), but more recent estimates show variable trends (Figure 2), depending on the choice of model and time frame used (Calambokidis and Barlow 2013). Population estimates for the entire North Pacific have also increased substantially from 1,200 in 1966 to approximately 18,000 - 20,000 whales in 2004 to 2006 (Calambokidis *et al*. 2008). Although these estimates are based on different methods and the earlier estimate is extremely uncertain, the growth rate implied by these estimates (6-7%) is consistent with growth rate of the California/Oregon/Washington stock.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

The proportion of calves in the California/Oregon/Washington stock from 1986 to 1994 appeared much lower than previously measured for humpback whales in other areas (Calambokidis and Steiger 1994), but in 1995-97 a greater proportion of calves were identified, and the 1997 reproductive rates for this population are closer to those reported for humpback whale populations in other regions (Calambokidis *et al*. 1998). Despite the apparently low proportion of calves, two independent lines of evidence indicate that this stock was growing in the 1980s and

early 1990s (Barlow 1994; Calambokidis *et al*. 2003) with a best estimate of 8% growth per year (Calambokidis *et al*. 1999). The current net productivity rate is unknown.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (1,876) <u>times</u> one half the estimated population growth rate for this stock of humpback whales (½ of 8%) <u>times</u> a recovery factor of 0.3 (for an endangered species; see Status of Stock section below regarding ESA listing status with $N_{min} > 1,500$ and $CV(N_{min}) < 0.50$), resulting in a PBR of 22. Because this stock spends approximately half its time outside the U.S. EEZ, the PBR allocation for U.S. waters is 11 whales per year.
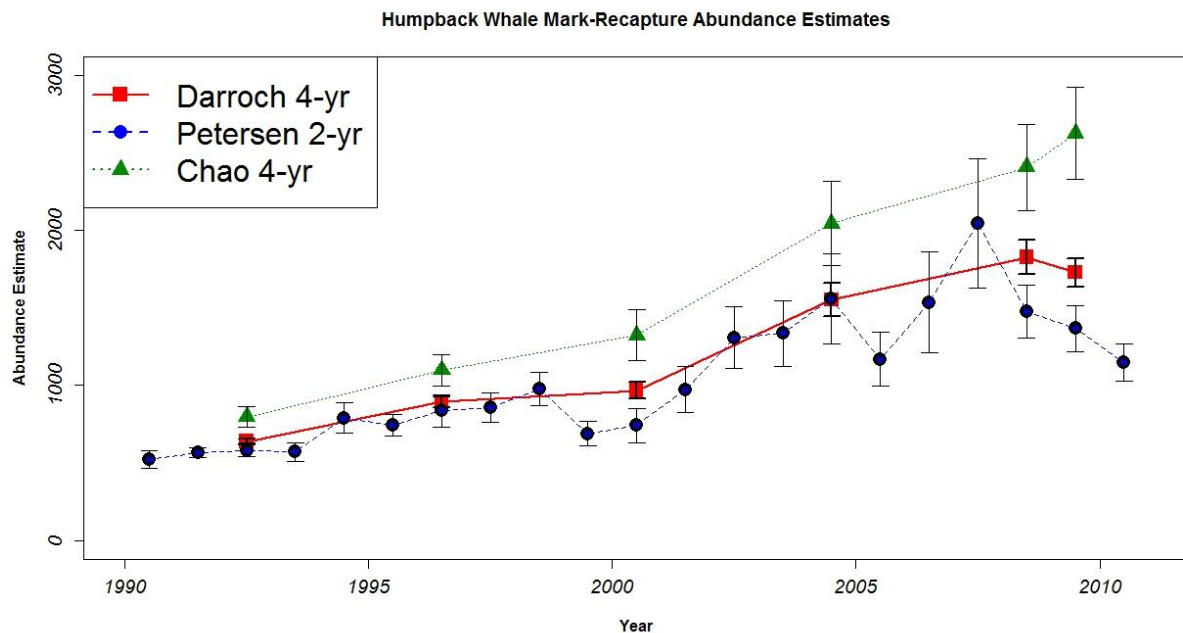
Figure 2. Mark-recapture estimates of humpback whale abundance in California and Oregon, 1991-2011, based on 3 different mark-recapture models and sampling periods (Calambokidis and Barlow 2013). Vertical bars indicate ±2 standard errors of each abundance estimate. Darroch and Chao models use 4 consecutive non-overlapping sample years, except for the last estimates, which use the four most recent years, but overlap with the next-to-last estimate (Calambokidis and Barlow 2013).

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

A total of 71 human-related interactions involving humpback whales are summarized for the 5-year period 2011-2015 by Carretta *et al.* (2017a). These records include serious and non-serious injuries and mortality involving pot/trap fisheries (n=34), unidentified fishery interactions (26), vessel strikes (9), gillnet fisheries (1) and marine debris (1). The number of serious injuries and mortalities for each category are summarized below. In addition, there were 19 entanglement and vessel strike records of 'unidentified whales' (totaling 15 serious injuries) during 2011-2015, some of which were certainly humpback whales. The number of serious injuries of 'unidentified whales' during 2011-2015 was therefore, 15 / 5 = 3 animals annually.

Fishery Information

Pot and trap fisheries are the most commonly documented source of serious injury and mortality of humpback whales in U.S. west coast waters (Carretta *et al*. 2013, 2015, 2016a), and entanglement reports have increased considerably since 2014. From 2011 to 2015, there were 34 documented interactions with pot and trap fisheries (Carretta *et al.* 2017a, Jannot *et al.* 2016). Twelve records (3 CA spot prawn pot + 8 Dungeness crab pot + 1 lobster pot) involved non-serious injuries resulting from human intervention to remove gear, or cases where animals were able to free themselves. Two records involved dead whales, including one humpback recovered in sablefish pot gear in offshore Oregon waters and one case where severed humpback flukes were found in southern California waters entangled in California Dungeness crab gear (Carretta *et al.* 2016, 2017a). The remaining 20 cases, once evaluated per the NMFS serious injury policy, resulted in a total of 15.5 serious injuries / 5 years, or 3.1

humpback whales annually (Table 1). This includes 10.25 serious injuries (from 13 cases) in unidentified trap/pot fisheries, 2.25 serious injuries (from 3 cases) in California Dungeness crab pot, 1.5 serious injuries (from 2 cases) in the CA recreational Dungeness crab pot fishery, 0.75 serious injury (from 1 case) in a generic Dungeness crab pot fishery (state unknown), and 0.75 serious injury (from 1 case) in the CA spot prawn trap fishery. Including the 2 deaths attributed to pot/traps, the minimum level of annual mortality and serious injury across all pot/trap fisheries is 15.5 serious injuries + 2 mortalities = 17.5 whales / 5 years = 3.5 whales annually. Two records (totaling 1.5 serious injuries are attributed to the *recreational* Dungeness crab fishery and thus, are not counted towards commercial fishery totals (but count against PBR, see Status of Stock Section). Thus, the number of *commercial* pot/trap fishery serious injuries and deaths totals 16 whales, or 16/5 = 3.2 whales annually (Table 1).

Table 1. Summary of available information on the incidental mortality and serious injury of humpback whales (California/Oregon/Washington stock) for commercial fisheries that are likely to take this species (Carretta *et al.* 2017a, Carretta *et al.* 2017b). Mean annual takes are based on 2011-2015 data unless noted otherwise. Serious injuries may include prorated serious injuries with values less than one (NOAA 2012), thus the sum of serious injury and mortality may not be a whole number.

Fishery Name	Year(s)	Data Type	Percent Observer Coverage	Observed Mortality (and serious injury)	Estimated mortality and serious injury (CV)	Mean Annual Takes (CV)
CA swordfish and thresher shark drift gillnet fishery	2011-2015	observer	24%	0[1]	0.1 (3)	< 0.02 (3)
CA halibut/white seabass and other species large mesh (≥3.5") set gillnet fishery	2010-2014	observer	9%	0	0	0 (n/a)
CA spot prawn pot	2011-2015	Strandings / sightings	n/a	0 (0.75)	n/a	≥ 0.15
Unspecified pot or trap fisheries (includes generic 'Dungeness' crab gear not attributed to a specific state fishery)	2011-2015	Strandings / sightings	n/a	0 (11)	n/a	≥ 2.2
CA Dungeness crab pot	2011-2015	Strandings / sightings	n/a	1 (2.25)	n/a	≥ 0.65
OR Dungeness crab pot[2]	2011-2015	Strandings / sightings	n/a	0 (0)	n/a	≥ 0
WA coastal Dungeness crab pot	2011-2015	Strandings / sightings	n/a	0 (0)	n/a	≥ 0
WA/OR/CA limited entry sablefish pot	2014	observer	31%	1 (0)	n/a[3]	≥ 0.2
unidentified fisheries	2011-2015	Strandings / sightings	n/a	3 (19)	n/a	≥ 4.4
Total Annual Takes						≥ 7.6

Gillnet (n=1) and unidentified fisheries (n=26) accounted for 27 interactions with humpback whales between 2011 and 2015 (Carretta *et al.* 2017a). Based on the proportion of humpback whale records where the type of fishing gear is positively identified, it is likely that most cases involving 'unidentified fisheries' represent pot and/or trap fisheries (Carretta *et al.* 2017a). Three records involved dead whales. The remaining 24 records, once evaluated per the NMFS serious injury policy, resulted in one non-serious injury and 19 serious injuries (16 cases x 0.75 = 12 prorated serious injuries, plus 7 non-prorated serious injuries). The total annual mortality and serious injury due to unidentified and gillnet fisheries from 2011 to 2015 sightings reports is 22 whales. The 5-year annual mean serious injury and mortality due to unidentified fisheries during this period is therefore 22 / 5 = 4.4 whales.

Three humpback whale entanglements (all released alive) were observed in the CA swordfish drift gillnet fishery from over 8,700 fishing sets monitored between 1990 and 2015 (Carretta *et al.* 2017b). Some opportunistic sightings of free-swimming humpback whales entangled in gillnets may also originate from this fishery. The most

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[1] There were no observations of humpback whales in this fishery during 2011-2015, but the model-based estimate of bycatch for this period results in a positive estimate of bycatch (Carretta *et al.* 2017b).
[2] There were 3 non-serious injuries involving humpback whales with this fishery from 2011-2015.
[3] No estimate of total bycatch has been generated for this fishery.

recent model-based estimate of humpback whale bycatch in this fishery for 2011-2015 is 0.4 whales (CV= 2.0), but it is estimated that only one-quarter of these entanglements represent serious injuries (Martin *et al.* 2015). The corresponding ratio estimate of bycatch for the same time period is zero (Carretta *et al.* 2017b). The model-based estimate is considered superior because it utilizes all 26 years of data for estimation, in contrast to the ratio estimate that uses only 2011-2015 data. The average annual estimated serious injury and mortality in the CA swordfish drift gillnet fishery is 0.02 whales (0.1 whales / 5 years).

Total commercial fishery serious injury and mortality of humpback whales for the period 2011-2015 is the sum of pot/trap fishery records (16), plus unidentified fishery records (22), plus estimates from the CA swordfish drift gillnet fishery (0.02), or 38 total whales. The mean annual serious injury and mortality from commercial fisheries during 2011-2015 is 38 whales / 5 years = 7.6 whales (Table 1). Most serious injury and mortality records from commercial fisheries reflect opportunistic stranding and at-sea sighting data and thus, represent minimum counts of impacts, for which no correction factor is currently available.

Despite an overall increase in the number of reported entanglements in recent years, increasing efforts to disentangle humpback whales from fisheries has led to an increase in the fraction of cases reported as non-serious injuries, due to the removal of gear from humpback whales that otherwise appear healthy. In the absence of human intervention, these records would have represented at least 8 additional serious injuries over the 5-year period 2011-2015 (Carretta *et al.* 2017a).

Ship Strikes

Nine humpback whales (4 deaths, 1.56 serious injuries, and 3 non-serious injuries) were reported struck by vessels between 2011 and 2015 (Carretta *et al.* 2017a). In addition, there was one serious injury to an unidentified large whale from a ship strike during this time (Carretta *et al.* 2017a). The average annual serious injury and mortality of humpback whales attributable to ship strikes during 2011-2015 is 1.1 whales per year (4 deaths, plus 1.56 serious injuries = 5.6 per 5 years). Ship strike mortality was recently estimated for humpback whales in the California Current (Rockwood *et al.* 2017), using an encounter theory model (Martin *et al.* 2015) that combined species distribution models of whale density (Becker *et al.* 2016), vessel traffic characteristics (size + speed + spatial use), along with whale movement patterns obtained from satellite-tagged animals in the region to estimate encounters that would result in mortality. The results of this study were published while this report was being prepared and the results will be fully incorporated into the draft 2018 stock assessment report for this species.

Other human-caused mortality and serious injury

A humpback whale was entangled in a research wave rider buoy in 2014. The whale is estimated to have been entangled for 3 weeks and had substantial necrotic tissue around the caudal peduncle. Although the whale was fully disentangled by a whale entanglement team, this animal was categorized as a serious injury[4] because of the necrotic condition of the caudal peduncle and the possibility that the whale would lose its flukes due to the severity of the entanglement (NOAA 2012, Carretta *et al.* 2016, 2017a).

STATUS OF STOCK

Approximately 15,000 humpback whales were taken from the North Pacific from 1919 to 1987 (Tonnessen and Johnsen 1982), and, of these, approximately 8,000 were taken from the west coast of Baja California, California, Oregon and Washington (Rice 1978), presumably from this stock. Shore-based whaling apparently depleted the humpback whale stock off California twice: once prior to 1925 (Clapham *et al.* 1997) and again between 1956 and 1965 (Rice 1974). There has been a prohibition on taking humpback whales since 1966. As a result of commercial whaling, humpback whales were listed as "endangered" under the Endangered Species Conservation Act of 1969. This protection was transferred to the Endangered Species Act (ESA) in 1973. The humpback whale ESA listing final rule (81 FR 62259, September 8, 2016) established 14 distinct population segments (DPSs) with different listing statuses. The CA/OR/WA humpback whale stock primarily includes whales from the endangered Central American DPS and the threatened Mexico DPS, plus a small number of whales from the non-listed Hawaii DPS. Humpback whale stock delineation under the MMPA is currently under review, and until this review is complete, the CA/OR/WA stock will continue to be considered endangered and depleted for MMPA management purposes (e.g., selection of a recovery factor, stock status). Consequently, the California/Oregon/ Washington stock is automatically considered as a "strategic" stock under the MMPA. The

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[4] This whale was initially listed as a non-serious injury in Carretta *et al*. (2016a) due to insufficient detail in the preliminary reporting. It is considered a serious injury for purposes of this stock assessment report.

estimated annual mortality and serious injury due to commercial fishery entanglements in 2011-2015 (7.6/yr) , non-fishery entanglements (0.2/yr), recreational crab pot fisheries (0.3/yr), plus ship strikes (1.1/yr), equals 9.2 animals. Although this is less than the stock's PBR (11) for U.S. waters, not all entangled or ship-struck whales are detected and the true rate of mortality and serious injury is almost certainly greater than 9.2. Most data on human-caused serious injury and mortality for this population is based on opportunistic stranding and at-sea sighting data and represents a minimum count of total impacts. There is currently no estimate of the fraction of anthropogenic injuries and deaths to humpback whales that are undocumented on the U.S. west coast. In addition to incidents involving humpback whales, an additional number of 'unidentified whales' (3/yr) were seriously injured between 2011-2015, some of which were certainly humpback whales, based on the observed proportion (40%) of all large whale injury cases identified as humpbacks during this period (Carretta *et al.* 2017a). Based on strandings and at sea observations, annual humpback whale mortality and serious injury in commercial fisheries (7.6/yr) is greater than 10% of the PBR; therefore, total fishery mortality and serious injury is not approaching zero mortality and serious injury rate. The California/Oregon/Washington stock showed a long-term increase in abundance from 1990 through approximately 2008 (Figure 2), but more recent estimates have shown variable trends.

Habitat Concerns

Increasing levels of anthropogenic sound in the world's oceans (Andrew *et al*. 2002), such as those produced by shipping traffic, or LFA (Low Frequency Active) sonar, have been identified as a habitat concern for whales, as it can reduce acoustic space used for communication (masking) (Clark *et al.* 2009, NOAA 2016). This can be particularly problematic for baleen whales that may communicate using low-frequency sound (Erbe 2016). Based on vocalizations (Richardson *et al*. 1995; Au *et al*. 2006), reactions to sound sources (Lien *et al*. 1990, 1992; Maybaum 1993), and anatomical studies (Hauser *et al*. 2001), humpback whales also appear to be sensitive to mid-frequency sounds, including those used in active sonar military exercises (U.S. Navy 2007).

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BLUE WHALE (*Balaenoptera musculus musculus*):
Eastern North Pacific Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

North Pacific blue whales were once thought to belong to as many as five separate populations (Reeves *et al.* 1998), but acoustic evidence suggests only two populations, in the eastern and western north Pacific, respectively (Stafford *et al*. 2001, Stafford 2003, McDonald *et al*. 2006, Monnahan *et al*. 2014). North Pacific blue whales produce two distinct acoustic calls, referred to as "northwestern" and "northeastern" types, and it has been proposed that these represent distinct populations with some degree of geographic overlap (Stafford *et al*. 2001, Stafford 2003, Monnahan *et al*. 2014). The northeastern call predominates in the Gulf of Alaska, the U.S. West Coast, and the eastern tropical Pacific, while the northwestern call predominates from south of the Aleutian Islands to the Kamchatka Peninsula in Russia, though both call types have been recorded concurrently in the Gulf of Alaska (Stafford *et al.* 2001, Stafford 2003). Both call types occur in lower latitudes in the central North Pacific, but differ in their seasonal patterns (Stafford *et al*. 2001). Blue whales satellite-tagged off California in late summer have been found to travel to the eastern tropical Pacific and the Costa Rica Dome area in winter (Mate *et al*. 1999, Bailey *et al.* 2009). Photographs of blue whales in California have also been matched to individuals photographed off the Queen Charlotte Islands in northern British Columbia and to one individual photographed in the northern Gulf of Alaska (Calambokidis *et al.* 2009a). Gilpatrick and Perryman (2008) showed that blue whales from California to Central America (the Eastern North Pacific stock) are on average, two meters shorter

Figure 1. Blue whale sighting locations based on aerial and summer/autumn shipboard surveys off California, Oregon, and Washington, 1991-2014 Dashed line represents the U.S. EEZ; thin lines represent completed transect effort for all surveys combined.

than blue whales measured from historic whaling records in the central and western north Pacific.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, the Eastern North Pacific Stock of blue whales includes animals found in the eastern North Pacific from the northern Gulf of Alaska to the eastern tropical Pacific. This definition is consistent with both the distribution of the northeastern call type, photogrammetric length determinations and with the known range of photographically identified individuals. Based on locations where the northeastern call type has been recorded, some individuals in this stock may range as far west as Wake Island and as far south as the Equator (Stafford *et al*. 1999, 2001). The U.S. West Coast is certainly one of the most important feeding areas in summer and fall (Figure 1), but, increasingly, blue whales from this stock have been found feeding to the north and south of this area during summer and fall. Nine 'biologically important areas' (BIAs) for blue whale feeding are identified off the California coast by Calambokidis *et al*. (2015), including six in southern California and three in central California. Most of this stock is believed to migrate south to spend the winter and spring in high productivity areas off Baja California, in the Gulf of California, and on the Costa Rica Dome. Given that these migratory destinations are areas of high productivity and given the observations of feeding in these areas, blue whales can be assumed to feed year round. Some individuals from this stock may be present year-round on the Costa Rica Dome (Reilly and Thayer 1990). However, it is also possible that some Southern Hemisphere blue whales might occur
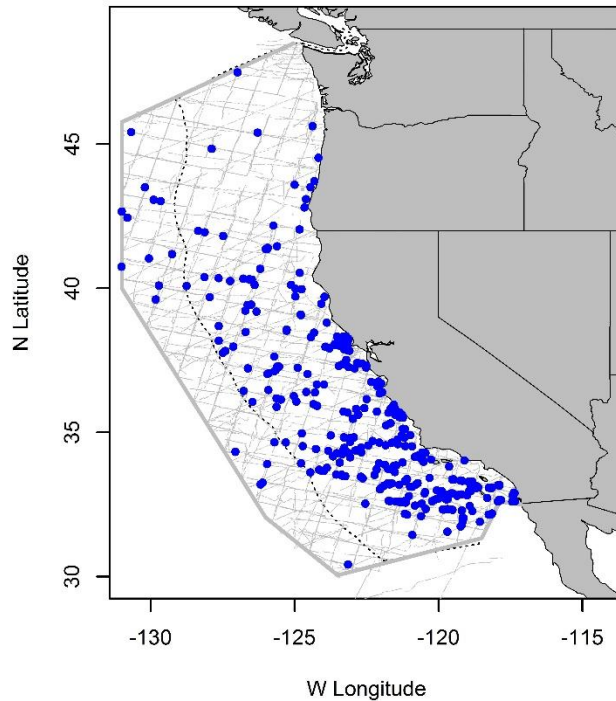
north of the equator during the austral winter. One other stock of North Pacific blue whales (the Central North Pacific stock) is recognized in the Pacific Marine Mammal Protection Act (MMPA) Stock Assessment Reports.

POPULATION SIZE

The size of the feeding stock of blue whales off the U.S. West Coast has been estimated recently by both line-transect and mark-recapture methods. Line-transect abundance estimates from summer/autumn research vessel surveys in the California Current ranged between approximately 400 and 800 animals from 2001 to 2008 (Barlow and Forney 2007, Barlow 2010). These estimates are considerably lower than previous line-transect estimates of approximately 1,900 animals obtained between 1991 and 1996 (Barlow 2010) (Figure 2). The lower abundance estimates appear to be related to a northward shift in the distribution of blue whales out of the study area (as far north as the Gulf of Alaska) and not a population decline (Barlow and Forney 2007, Calambokidis *et al*. 2009a). Mark-recapture estimates are often negatively biased by individual heterogeneity in sighting probabilities (Hammond 1986); however, Calambokidis *et al*. (2010) minimize such effects by selecting one sample that was taken randomly with respect to distance from the coast. Because some fraction of the population is always outside the survey area, the line-transect and mark recapture estimation methods provide different measures of abundance for this stock. Line transect estimates reflect the average density and abundance of blue whales in the study area during summer and autumn surveys, while mark recapture estimates provide an estimate of total population size. New photographic mark-recapture estimates of abundance for the period 2005 to 2011 presented by Calambokidis and Barlow (2013) range from approximately 1,000 to 2,300 animals, with the most consistent estimates represented by a 4-yr sampling period Chao model that incorporates individual capture heterogeneity over time. The Chao model consistently yielded estimates of approximately 1,500 whales (Figure 2). The best estimate of blue whale abundance is taken from the Chao model results of Calambokidis and Barlow (2013) for the period 2008 to 2011, or 1,647 (CV=0.07) whales.

Minimum Population Estimate

The minimum population estimate for blue whales is taken as the lower 20th percentile of the log-normal distribution of abundance estimated from the mark-recapture estimate, or approximately 1,551.

Current Population Trend

Mark-recapture estimates provide the best indicator of population trends for this stock, because of recent northward shifts in blue whale distribution that negatively bias line-transect estimates. Based on mark-recapture estimates shown in Figure 2, there is no evidence of a population size increase in this blue whale population since the early 1990s. While the Petersen mark-recapture estimates show an apparent increase in blue whale abundance since 1996, the estimation errors associated with these estimates are also much higher than for the Chao estimates (Figure 2). Monnahan *et al*. (2015) used a population dynamics model to estimate that the eastern Pacific blue whale population was at 97% of carrying capacity in 2013 and suggest that density dependence and not impacts from ship strikes, explains the observed lack of a population size increase since the early 1990s. The authors estimate that the eastern North Pacific population likely did not drop below 460 whales during the last century, despite being targeted by commercial whaling.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Based on mark-recapture estimates from the US West Coast and Baja California, Mexico, Calambokidis *et al*. (2009b) estimate a rate of increase just under 3% per year, but it is not known if that corresponds to the maximum growth rate of this stock.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (1,551) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.3 (for an endangered species which has a minimum abundance greater than 1,500 and a $CV_{Nmin}<0.5$), resulting in a PBR of 9.3. Because whales in this stock spends approximately three quarters of their time outside the U.S. EEZ, the PBR allocation for U.S. waters is one-quarter of this total, or 2.3 whales per year.
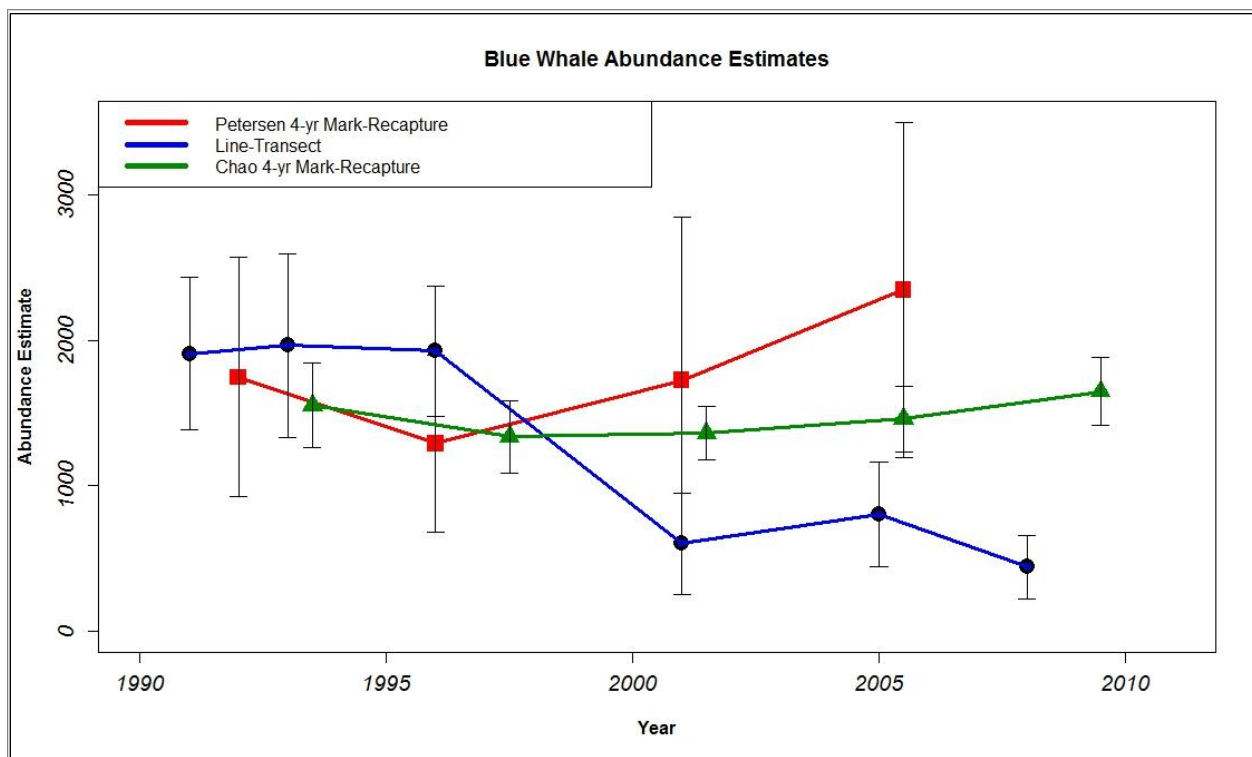
Figure 2. Estimates of blue whale abundance from line-transect and photographic mark-recapture surveys, 1991 to 2011 (Barlow and Forney 2007, Barlow 2010, Calambokidis and Barlow 2013). Vertical bars indicate ±2 standard errors of each abundance estimate.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY
Fisheries Information

A seriously-injured blue whale was sighted entangled in unidentified pot/trap gear offshore of southern California in 2015, the first documented blue whale entanglement in a commercial fishery in this region (Carretta *et al.* 2017a). There have been no observed entanglements of blue whales in the California swordfish drift gillnet fishery during a 26-year observer program that includes 8,711 observed fishing sets from 1990-2015 (Julian and Beeson 1998, Carretta *et al*. 2004, Carretta *et al*. 2017b). Some gillnet mortality of large whales may go unobserved because whales swim away with a portion of the net; however, fishermen report that large rorquals usually swim through nets without entangling and with very little damage to the nets. Gillnets have been documented to entangle marine mammals off Baja California (Sosa-Nishizaki *et al*. 1993), but no recent bycatch data from Mexico are available.

Table 1. Summary of available information on the incidental mortality and injury of blue whales (Eastern North Pacific stock) for commercial fisheries that might take this species (Carretta *et al.* 2017a, 2017b).

Fishery Name	Year(s)	Data Type	Percent Observer Coverage	Observed Mortality (and serious injury)	Estimated mortality and/or serious injury (CV in parentheses)	Mean Annual Takes (CV in parentheses)
Unidentified pot/trap fishery	2011-2015	opportunistic reports	n/a	0 (1)	1 (n/a)	≥ 0.2
CA/OR thresher shark/swordfish drift gillnet fishery	2011-2015	observer	24%	0	0	0 (n/a)
Total Annual Takes						0 (n/a)

Ship Strikes

No ship strikes of blue whales were recorded in the most recent 5-year period, 2011-2015, but there was one ship strike serious injury of an unidentified large whale during this same period (Carretta *et al.* 2017a). Ship strikes

were implicated in the deaths of four blue whales and the serious injury of a fifth whale between 2009 and 2013 (Carretta *et al*. 2015). Five deaths occurred in 2007, the highest number recorded for any year. The remaining four ship strike deaths occurred in 2009 (2) and 2010 (2). No methods have been developed to prorate the number of unidentified whale ship strike cases to species, because identified cases are likely biased towards species that are large, easy to identify, and more likely to be detected, such as blue and fin whales. Most observed blue whale ship strikes have been in the southern California Bight, where large container ship ports overlap with seasonal blue whale distribution (Berman-Kowalewski *et al*. 2010). Several blue whales have been photographed in California with large gashes in their dorsal surface that appear to be from ship strikes. Including ship strike records identified to species and prorated serious injuries, blue whale mortality and injuries attributed to ship strikes in California waters was zero during 2011-2015 (Carretta *et al.* 2017a). NOAA previously implemented a mitigation plan that includes NOAA weather radio and U.S. Coast Guard advisory broadcasts to mariners entering the Santa Barbara Channel to be observant for whales, along with recommendations that mariners transit the channel at 10 knots or less. The Channel Islands National Marine Sanctuary also developed a blue whale/ship strike response plan, which involved weekly overflights to record whale locations. Documented ship strike deaths and serious injuries are derived from actual counts of whale carcasses and should be considered minimum values. Where evaluated, estimates of detection rates of cetacean carcasses are consistently quite low across different regions and species (<1% to 17%), highlighting that observed numbers are unrepresentative of true impacts (Kraus *et al*. 2005, Perrin *et al*. 2011, Williams *et al*. 2011, Prado *et al*. 2013). Due to this negative bias, Redfern *et al*. (2013) stress that the number of observed ship strike deaths of blue whales in the California Current likely exceeds PBR. Ship strike mortality was recently estimated for blue whales in the California Current (Rockwood *et al*. 2017), using an encounter theory model (Martin *et al*. 2015) that combined species distribution models of whale density (Becker *et al*. 2016), vessel traffic characteristics (size + speed + spatial use), along with whale movement patterns obtained from satellite-tagged whales in the region to estimate encounters that would result in mortality. The results of this study were published while this report was being prepared and the results will be fully incorporated into the draft 2018 stock assessment report for this species.

Impacts of ship strikes on population recovery of the eastern North Pacific blue whale population were assessed by Monnahan *et al*. (2015). Their population dynamics model incorporated data on historic whaling removals, levels of ship strikes, and projected numbers of vessels using the region through 2050. The authors concluded (based on 10 ship strike deaths per year) that this stock was at 97% of carrying capacity in 2013 and that current ship strike levels do not pose a threat to the status of this stock. These authors also analyzed the status of the blue whale stock based on a 'high case' of annual ship strike deaths (35/yr) and concluded that under that scenario, the stock would have been at approximately 91% of carrying capacity in 2013. Caveats to the carrying capacity analysis include the assumption that the population was already at carrying capacity prior to commercial whaling of this stock in the early 20th century and that carrying capacity has not changed appreciably since that time (Monnahan *et al*. 2015).

Habitat Concerns

Increasing levels of anthropogenic sound in the world's oceans has been suggested to be a habitat concern for blue whales (Reeves *et al*. 1998, Andrew *et al*. 2002). Tagged blue whales exposed to simulated mid-frequency sonar and pseudo-random noise demonstrated a variety of behavioral responses, including no change in behavior, termination of deep dives, directed travel away from sound sources, and cessation of feeding (Goldbogen *et al*. 2013). Behavioral responses were highly dependent upon the type of sound source and the behavioral state of the animal at the time of exposure. Deep-feeding and non-feeding whales reacted more strongly to experimental sound sources than surface-feeding whales that typically showed no change in behavior. The authors stated that behavioral responses to such sounds are influenced by a complex interaction of behavioral state, environmental context, and prior exposure of individuals to such sound sources. One concern expressed by the authors is if blue whales did not habituate to such sounds near feeding areas that "repeated exposures could negatively impact individual feeding performance, body condition and ultimately fitness and potentially population health." Currently, no evidence indicates that such reduced population health exists, but such evidence would be difficult to differentiate from natural sources of reduced fitness or mortality in the population. Nine blue whale feeding areas identified off the California coast by Calambokidis *et al*. (2015) represent a diversity of nearshore and offshore habitats that overlap with a variety of anthropogenic activities, including shipping, oil and gas extraction, and military activities.

STATUS OF STOCK

The reported take of North Pacific blue whales by commercial whalers totaled 9,500 between 1910 and 1965 (Ohsumi and Wada 1972). Approximately 3,000 of these were taken from the west coast of North America from Baja California, Mexico to British Columbia, Canada (Tonnessen and Johnsen 1982; Rice 1992; Clapham *et al*. 1997; Rice 1974). Recently, Monnahan *et al*. (2014) estimated that 3,411 blue whales (95% range 2,593–4,114) were removed

from the eastern North Pacific populations between 1905 and 1971. Blue whales in the North Pacific were given protected status by the IWC in 1966, but Doroshenko (2000) reported that a small number of blue whales were taken illegally by Soviet whalers after that date. As a result of commercial whaling, blue whales were listed as "endangered" under the Endangered Species Conservation Act of 1969. This protection was transferred to the Endangered Species Act in 1973. Despite a current analysis suggesting that the Eastern North Pacific population is at 97% of carrying capacity (Monnahan *et al*. 2015), blue whales are listed as "endangered", and consequently the Eastern North Pacific stock is automatically considered a "depleted" and "strategic" stock under the MMPA. Conclusions about the population's current status relative to carrying capacity depend upon assumptions that the population was already at carrying capacity before commercial whaling impacted the population in the early 1900s, and that carrying capacity has remained relatively constant since that time (Monnahan *et al*. 2015). If carrying capacity has changed significantly in the last century, conclusions regarding the status of this population would necessarily change (Monnahan *et al*. 2015). The observed annual incidental mortality and injury rate (0/year) from ship strikes from 2011-2015 is less than the calculated PBR (2.3) for this stock, but this rate does not include unidentified large whales struck by vessels, some of which may have been blue whales, nor does it include undetected and unreported ship strikes of blue whales. While Redfern *et al.* (2013) noted that the number of blue whales struck by ships in the California Current likely exceeds the PBR for this stock, Monnahan *et al*. (2015) proposed that observed ship strike levels do not pose a threat to the status of this stock. The current annual level of serious injury and mortality due to commercial fisheries (≥0.2) for this stock is less than 10% of the stock's PBR, and thus, is approaching zero mortality and serious injury rate.

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ROUGH-TOOTHED DOLPHIN (*Steno bredanensis*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Rough-toothed dolphins are found throughout the world in tropical and warm-temperate waters (Perrin et al. 2009). They are present around all the main Hawaiian Islands, though are relatively uncommon near Maui and the 4-Islands region (Baird et al. 2013) and have been observed close to the islands and atolls at least as far northwest as Pearl and Hermes Reef (Bradford et al. 2017). Rough-toothed dolphins were occasionally seen offshore throughout the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands during both 2002 and 2010 surveys (Barlow 2006, Bradford et al. 2017; Figure 1).

Population structure in rough-toothed dolphins was recently examined using genetic samples from several tropical and sub-tropical island areas in the Pacific. Albertson et al. (2016) found significant differentiation in mtDNA and nuDNA from samples collected at Hawaii Island versus all other Hawaiian Island areas sampled. Estimates of differentiation among Kauai, Oahu, and the northwestern

Figure 1. Rough-toothed dolphin sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard cetacean surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford et al 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

Hawaiian Islands (NWHI) were lower and not statistically significant. Based on their result, Albertson et al. (2016) suggest that Hawaii Island warrants designation as a separate island-associated stock. Evaluation of individual rough-toothed dolphin encounters indicate differences in group sizes, habitat use, and behavior between groups seen near Hawaii Island and those seen near Kauai and Niihau (Baird et al 2008).Photographic identification studies suggested that dispersal rates between the islands of Kauai/Niihau and Hawaii do not exceed 2% per year (Baird et al. 2008). Resighting rates off the island of Hawaii are high, with 75% of well-marked individuals resighted on two or more occasions, suggesting high site fidelity and low population size. Movement data from 17 individual rough-toothed dolphins tagged near Kauai and Niihau show all individuals remained associated with Kauai with exception of one individual that moved from Kauai and Oahu and back (Baird 2016). The available genetics, movements, and social affiliation data suggest that there is at least one island-associated stock in the main Hawaiian Islands (MHI). Delineation of island-associated stocks in Hawaii is under review (Martien et al. 2016). Rough-toothed dolphins have also been documented in American Samoan waters (Oleson 2009).

For the Marine Mammal Protection Act (MMPA) stock assessment reports, there are two Pacific management stocks: 1) The Hawaii Stock (this report), and 2) the American Samoa Stock. The Hawaiian stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from the U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for rough-toothed dolphins, resulting in an abundance estimate of 72,528 (CV = 0.39) rough-toothed dolphins (Bradford et al. 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 8,709 (CV=0.45) rough-toothed dolphins (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small
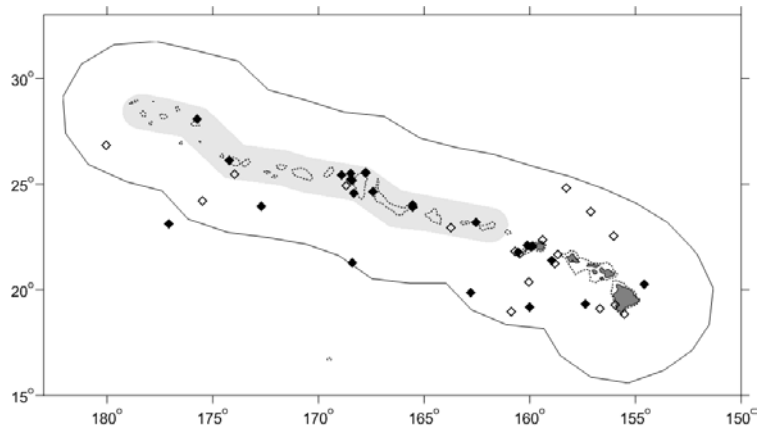
dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. A population estimate for this species has been made in the eastern tropical Pacific (Wade and Gerrodette 1993), but it is not known whether these animals are part of the same population that occurs around the Hawaiian Islands. Mark-recapture estimates for the islands of Kauai/Nihau and Hawaii were derived from identification photographs obtained between 2003 and 2006, resulting in estimates of 1,665 (CV=0.33) around Kauai/Niihau and 198 (CV=0.12) around the island of Hawaii (Baird *et al.* 2008). Such estimates may be representative of smaller island-associated populations at those island areas.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al 1995) of the 2010 abundance estimate or 52,833 rough-toothed dolphins within the Hawaiian Islands EEZ.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of rough-toothed dolphins is calculated as the minimum population size within the U.S. EEZ of the Hawaiian Islands (52,833) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.4 (for a stock of unknown status with a Hawaiian Islands EEZ fishery mortality and serious injury rate CV > 0.8 ; Wade and Angliss 1997), resulting in a PBR of 423 rough-toothed dolphins per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. Rough-toothed dolphins are known to take bait and catch from several Hawaiian sport and commercial fisheries operating near the main islands (Shallenberger 1981; Schlais 1984; Nitta and Henderson 1993). They have been specifically reported to interact with the day handline fishery for tuna (palu-ahi), the night handline fishery for tuna (ika-shibi), and the troll fishery for
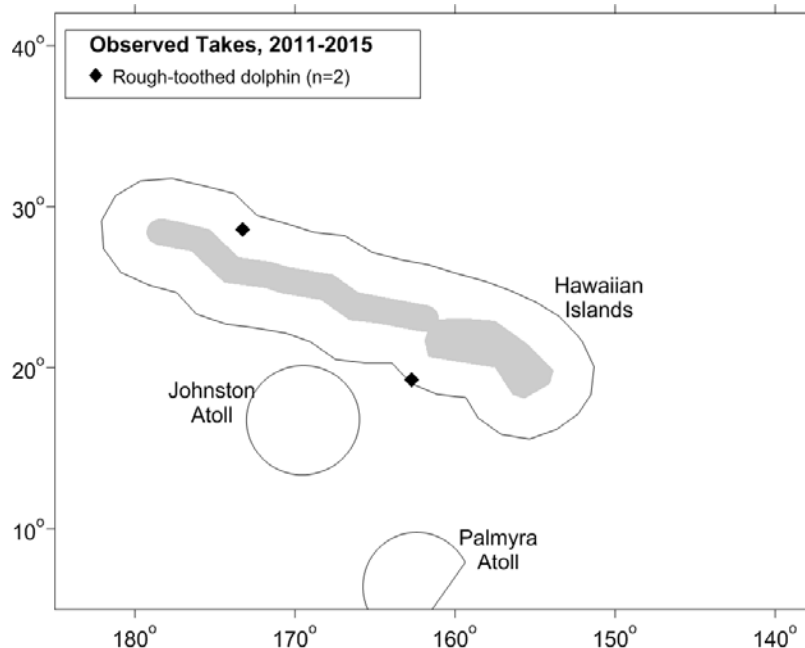

Figure 3. Locations of observed rough-toothed dolphin takes (filled diamonds) in the Hawaii-based longline fishery, 2011-2015. Solid lines represent the U. S. EEZ. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

billfish and tuna (Schlais 1984; Nitta and Henderson 1993). Baird et al. (2008) reported increased vessel avoidance of boats by rough-toothed dolphins off the island of Hawaii relative to those off Kauai or Niihau and attributed this to possible shooting of dolphins that are stealing bait or catch from recreational fisherman off the island of Hawaii (Kuljis 1983). One rough-toothed dolphin was observed off the Kona coast trailing 25-30 ft. of heavy line with two plastic jugs attached to the end of the line (Bradford and Lyman in review). The jugs were cut from the gear when other attempts (through pressure on the line) did not result in the removal of any other line or hooks, though all other trailing gear remained on the dolphin. This dolphin was considered seriously injured based on the amount of trailing gear. The source of the gear is not known. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line fisheries because these fisheries are not observed or monitored for protected species bycatch.

Table 1. Summary of available information on incidental mortality and serious injury of rough-toothed McCracken 2017). Mean annual takes are based on 2011-2015 data unless indicated otherwise. Information on all observed takes (T) and combined mortality events and serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome.

| Fishery Name | Year | Data Type | Percent Observer Coverage | Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of rough-toothed dolphins | | | |
| | | | | Outside U.S. EEZs | | Hawaiian EEZ | |
				Obs. T/MSI	Estimated M&SI (CV)	Obs. T/MSI	Estimated M&SI (CV)
Hawaii-based deep-set longline fishery	2011	Observer data	20%	0	0 (-)	0	0 (-)
	2012		20%	0	0 (-)	0	0 (-)
	2013		20%	0	0 (-)	1/1	5 (0.9)
	2014		21%	0	0 (-)	0	0 (-)
	2015		21%	0	0 (-)	0	0 (-)
Mean Estimated Annual Take (CV)					0 (-)		**1.1 (1.1)**
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	0	0	0	0
	2012		100%	0	0	0	0
	2013		100%	0	0	1/1	1
	2014		100%	0	0	0	0
	2015		100%	0	0	0	0
Mean Annual Takes (100% coverage)				**0**			**1**
Minimum total annual takes within U.S. EEZ							**2.1 (1.1)**

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Between 2011 and 2015, one rough-toothed dolphin was observed hooked or entangled in the SSLL fishery (100% observer coverage) and one in the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). Both of these interactions occurred inside the Hawaiian Islands EEZ and both dolphins were observed dead (Bradford 2017, Bradford and Forney 2017). Average 5-yr estimates of annual mortality and serious injury for rough-toothed dolphins during 2011-2015 are 2.1 (CV = 1.1) rough-toothed dolphins within the Hawaiian Islands EEZ and 0 dolphins outside of U.S. EEZs (Table 1, McCracken 2017). Four additional unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been rough-toothed dolphins.

STATUS OF STOCK

The Hawaii stock of rough-toothed dolphins is not considered strategic under the 1994 amendments to the MMPA, The status of rough-toothed dolphins in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Rough-toothed dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. One rough-toothed dolphin has been observed entangled in gear and a 5-yr average of 2.1 dolphins have been killed or seriously injured in the deep-set longline fishery. There is no systematic monitoring for interactions with protected species within near-shore fisheries that may take this species, thus total mean annual takes are undetermined.

However, the total number of killed or seriously injured (2.3) is significantly lower than PBR (423), such that the fishery-related mortality or serious injuries rate for the entire Hawaii stock can be considered to be insignificant and approaching zero. Island-associated populations of rough-toothed dolphins may experience relatively greater rates of fisheries mortality and serious injury. One rough-toothed dolphin stranded in the main Hawaiian Islands tested positive for *Brucella* (Chernov, 2010) and another for *Morbillivirus* (Jacob 2012). *Brucella* is a bacterial infection that if common in the population may limit recruitment by compromising male and female reproductive systems, and can also cause neurological disorders that may result in death (Van Bressem et al. 2009). Although *morbillivus* is known to trigger lethal disease in cetaceans (Van Bressem et al. 2009), its impact on the health of the stranded animal is not known as it was found in only a few tested tissues (Jacob et al. 2016). The presence of *morbillivirus* in 10 species (Jacob et al. 2016) and *Brucella* in 3 species (Chernov 2010, West unpublished data) raises concerns about the history and prevalence of these diseases in Hawaii and the potential population impacts, including cumulative impacts of disease with other stressors. It is not known if *Brucella or Morbillivirus* are common in the Hawaii stock.

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RISSO'S DOLPHIN (*Grampus griseus*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Risso's dolphins are found in tropical to warm-temperate waters worldwide (Perrin et al. 2009). Risso's dolphins represent less than 1% of all odontocete sightings in leeward surveys of the main Hawaii Islands from 2000 to 2012 (Baird et al. 2013); however, six sightings were made during a 2002 survey and 12 during a 2010 survey of the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands (Barlow 2006, Bradford et al. 2017; Figure 1). Most sightings of Risso's dolphins occur in deep waters offshore. A single satellite tagged animal moved broadly between offshore waters off Kona, Kohoolawe, and Lanai over a 2 week period (Baird 2016). Sighting, habitat, and limited movement data do not appear to support finer population structure in Hawaiian waters.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, Risso's dolphins within the Pacific U.S. EEZ are divided into two discrete,

Figure 1. Risso's dolphin sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard cetacean surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford et al. 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Dark and light gray shading indicate the original and expanded area of Papahanaumokuakea Marine National Monument. Dotted line is the 1000 m isobath.

non-contiguous areas: 1) Hawaiian waters (this report), and 2) waters off California, Oregon and Washington. The Hawaiian stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for Risso's dolphins, resulting in an abundance estimate of 11,613 (CV = 0.43) Risso's dolphins (Bradford et al. 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 2,372 (CV=0.97) Risso's dolphins (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Population estimates have been made off Japan (Miyashita 1993), in the eastern tropical Pacific (Wade and Gerrodette 1993), and off the U.S. West Coast (Barlow and Forney 2007), but it is not known whether these animals are part of the same population that occurs around the Hawaiian Islands and in the central North Pacific.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al 1995) of the 2010 abundance estimate, or 8,210 Risso's dolphins within the Hawaiian Islands EEZ.
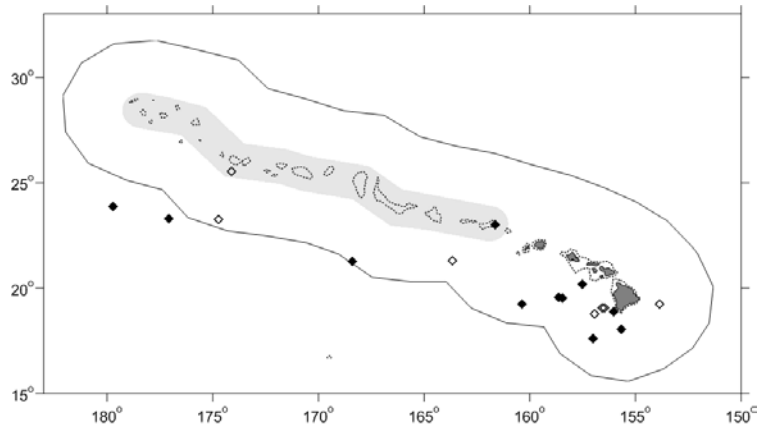
Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for Hawaiian animals.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of Risso's dolphins is calculated as the minimum population size within the U.S. EEZ of the Hawaiian Islands (8,210) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.5 (for a stock of unknown status with no known fishery mortality and serious injury within the Hawaii EEZ; Wade and Angliss 1997), resulting in a PBR of 82 Risso's dolphins per year.

HUMAN CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. No interactions between nearshore fisheries and Risso's dolphins have been reported in Hawaiian waters. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line fisheries because these fisheries are not observed or monitored for protected species bycatch.

There are currently two distinct longline fisheries based in

Figure 2. Locations of Risso's dolphin takes (filled diamonds) in Hawaii-based longline fisheries, 2011-2015. Solid lines represent the U.S. EEZs. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, 13 Risso's dolphins were observed killed or seriously injured in the SSLL fishery (100% observer coverage), and 2 Risso's dolphins were observed killed or seriously injured in the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). One Risso's dolphin in the DSLL fishery and four in the SSLL fishery were killed, 9 in the SSLL fishery and one in the DSLL fishery were considered to have been seriously injured, and the remaining three interactions in the SSLL fishery were determined to be not seriously injured or could not be determined based on an evaluation of the observer's description of the interaction. When otherwise undetermined, the injury status of takes is prorated to serious versus non-serious using the historic rate of serious injury within the observed takes. Average 5-yr estimates of annual mortality and serious injury for 2011-2015 are 5.1 (CV = 0.9) Risso's dolphins outside of U.S. EEZs, and 0 within the Hawaiian Islands EEZ (Table 1, McCracken 2017). Four additional unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been Risso's dolphins.
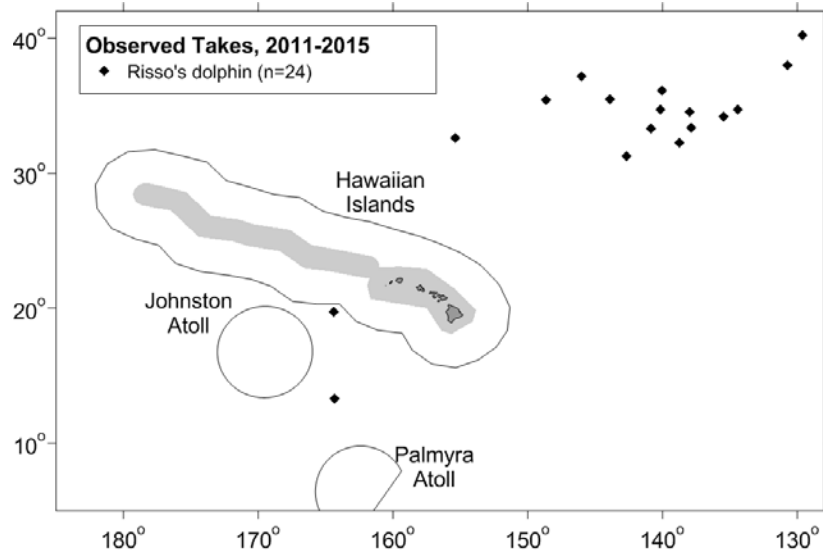
Table 1. Summary of available information on incidental mortality and serious injury of Risso's dolphin (Hawaii stock) in commercial longline fisheries, within and outside of U.S. EEZs (McCracken 2017). Mean annual takes are based on 2011-2015 data unless indicated otherwise. Information on all observed takes (T) and combined mortality events & serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome.

Fishery Name	Year	Data Type	Percent Observer Coverage	Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of Risso's dolphins			
				Outside U.S. EEZs		Hawaiian EEZ	
				Obs. T/MSI	Estimated M&SI (CV)	Obs. T/MSI	Estimated M&SI (CV)
Hawaii-based deep-set longline fishery	2011	Observer data	20%	0	0 (-)	0	0 (-)
	2012		20%	0	0 (-)	0	0 (-)
	2013		20%	0	0 (-)	0	0 (-)
	2014		21%	0	0 (-)	0	0 (-)
	2015		21%	2/2	10 (0.6)	0	0 (-)
Mean Estimated Annual Take (CV)					**1.9 (0.9)**		**0 (-)**
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	4/3	3	0	0
	2012		100%	0/0	0	0	0
	2013		100%	3/2	2	0	0
	2014		100%	6/6[†]	6	0	0
	2015		100%	3/3	3	0	0
Mean Annual Takes (100% coverage)					**3.2**		**0**
Minimum total annual takes within U.S. EEZ							**0 (-)**

[†] Injury status could not be determined based on information collected by the observer. Injury status is prorated (see text).

STATUS OF STOCK

The Hawaii stock of Risso's dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of Risso's dolphins in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Risso's dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries the total fishery mortality and serious injury can be considered to be insignificant and approaching zero. One Risso's dolphin stranded on the MHI tested positive for *Morbillivirus* (Jacob et al. 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters, all identified as a unique strain of *morbillivirus*, (Jacob et al. 2016), raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including cumulative impacts of disease with other stressors.

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COMMON BOTTLENOSE DOLPHIN (*Tursiops truncatus truncatus*):
Hawaiian Islands Stock Complex- Kauai/Niihau, Oahu, 4-Islands, Hawaii Island, Hawaii Pelagic

STOCK DEFINITION AND GEOGRAPHIC RANGE

Common bottlenose dolphins are widely distributed throughout the world in tropical and warm-temperate waters (Perrin *et al.* 2009). The species is primarily coastal in much of its range, but there are populations in some offshore deepwater areas as well. Bottlenose dolphins are common throughout the Hawaiian Islands, from the island of Hawaii to Kure Atoll (Shallenberger 1981, Baird *et al.* 2013).Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in 18 sightings in 2002 and 20 sightings in 2010 (Barlow 2006, Bradford *et al.* 2017; Figure 1). In the Hawaiian Islands, bottlenose dolphins are found in shallow inshore waters and deep water (Baird *et al.* 2009).

Separate offshore and coastal forms of bottlenose dolphins have been identified along continental coasts (Ross and Cockcroft 1990; Van Waerebeek *et al.* 1990), and there is evidence that similar onshore-offshore forms may exist in Hawaiian waters. In their analysis of sightings of bottlenose dolphins in the eastern tropical Pacific (ETP), Scott and Chivers (1990) noted a large hiatus between the westernmost sightings and the Hawaiian Islands. These data suggest that bottlenose dolphins in Hawaiian waters belong to a separate stock from those in the ETP. Furthermore, recent photo-identification and genetic studies off Oahu, Maui, Lanai, Kauai, Niihau, and Hawaii suggest limited movement of bottlenose dolphins between islands and offshore waters (Baird *et al.* 2009; Martien *et al.* 2012). These data suggest the existence of demographically distinct resident populations at each of the four main Hawaiian Island groups – Kauai & Niihau, Oahu, the '4-island' region (Molokai, Lanai, Maui, Kahoolawe), and Hawaii. Genetic data support inclusion of bottlenose dolphins in deeper waters surrounding the main Hawaiian Islands as part of the broadly distributed pelagic population (Martien *et al.* 2012).

Over 99% of the bottlenose dolphins linked through photo-identification to one of the insular populations around the main Hawaiian Islands (Baird *et al.* 2009) have been documented

Figure 1. Bottlenose dolphin sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard cetacean surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobaths. Insular stock boundaries are shown in Figure 2.
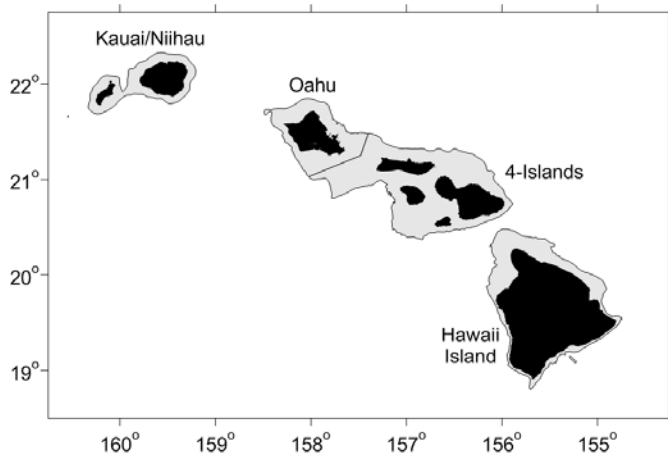
Figure 2. Main Hawaiian Islands insular bottlenose dolphin stock boundaries (gray shading). Areas beyond the 1000 m isobath represent the pelagic stock range.

in waters of 1000 m or less (Martien & Baird 2009). Based on these data, Martien and Baird (2009) suggested that the boundaries between the insular stocks and the Hawaii Pelagic stock be placed along the 1000 m isobath. Since that isobath does not separate Oahu from the 4-Islands Region, the boundary between those stocks runs approximately equidistant between the 500 m isobaths around Oahu and the 4-Islands Region, through the middle of Kaiwi Channel.
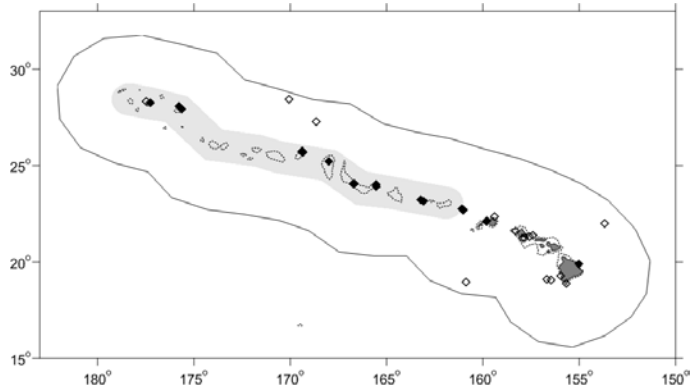
These boundaries (Figure 2) are applied in this report to recognize separate insular and pelagic bottlenose dolphin stocks for management (NMFS 2005). These boundaries may be revised in the future as additional information becomes available. To date, no data are available regarding population structure of bottlenose dolphins in the Northwestern Hawaiian Islands (NWHI), though sightings during the 2010 survey indicate they are commonly found close to the islands and atolls there (Bradford *et al.* 2017). Given the evidence for island resident populations in the main Hawaiian Islands, the larger distances between islands in the NWHI, and the finding of population structure within the NWHI in other dolphin species (Andrews 2010), it is likely that additional demographically independent populations of bottlenose dolphins exist in the NWHI. However, until data become available upon which to base stock designations in this area, the NWHI will remain part of the Hawaii Pelagic Stock. For the Marine Mammal Protection Act (MMPA) Pacific stock assessment reports, bottlenose dolphins within the Pacific U.S. EEZ are divided into seven stocks: 1) California, Oregon and Washington offshore stock, 2) California coastal stock, and five Pacific Islands Region management stocks (this report): 3) Kauai/Niihau, 4) Oahu, 5) 4-Islands (Molokai, Lanai, Maui, Kahoolawe), 6) Hawaii Island and 7) the Hawaiian Pelagic Stock, including animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of the Hawaii pelagic stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005). Estimates of abundance, potential biological removals, and status determinations for the five Hawaiian stocks are presented separately below.

HUMAN CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaii fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. There are at least two reports of entangled bottlenose dolphins dying in gillnets off Maui (Nitta and Henderson 1993, Maldini 2003, Bradford & Lyman 2013). Although gillnet fisheries are not observed or monitored through any State or Federal program, State regulations now ban gillnetting around Maui and much of Oahu and require gillnet fishermen to monitor their nets for bycatch every 30 minutes in those areas where gillnetting is permitted. In 2009 and 2013, a bottlenose dolphin was observed off the Kona coast with hook and line trailing from its mouth. In the latter case, the trailing gear was entangled around the pectoral fin, and appeared to be restricting the animal's movement. The bulk of the trailing gear was cut free by a diver, but the hook and an unknown amount of line remained in the dolphin's mouth. In both cases the dolphins were known to frequent aquaculture pens off the Kona Coast of the island of Hawaii (Bradford & Lyman 2015, in review). Based on the description and photographs or video, both injuries were considered serious under the most recently developed criteria for assessing serious injury in marine mammals (NMFS 2012). The 2009 animal was resighted in February 2012 without the fish hook and in normal body condition, such that this injury is no longer considered serious. The 2013 animal has not been resighted. The responsible fishery is not known. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line or gillnet fisheries because these fisheries are not observed or monitored for protected species bycatch.

Bottlenose dolphins are one of the species commonly reported to steal bait and catch from several Hawaii sport and commercial fisheries (Nitta &
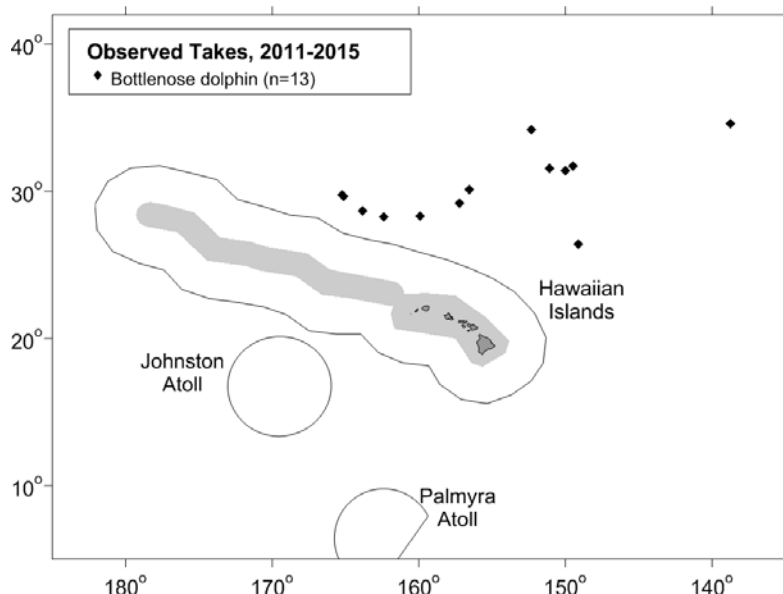

Figure 3. Locations of observed Pelagic Stock bottlenose dolphin takes (filled diamonds) in the Hawaii-based longline fishery, 2011-2015. Solid lines represent the U. S. EEZ. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

Henderson 1993, Schlais 1984). Observations of bottlenose dolphins stealing bait or catch have been made in the day handline fishery (palu-ahi) for tuna, the night handline fishery for tuna (ika-shibi), the handline fishery for mackerel scad, the troll fishery for billfish and tuna, and the inshore set gillnet fishery (Nitta and Henderson 1993). Nitta & Henderson (1993) indicated that bottlenose dolphins remove bait and catch from handlines used to catch bottomfish off the island of Hawaii and Kaula Rock and formerly on several banks of the Northwestern Hawaiian Islands. Fishermen claim interactions with dolphins that steal bait and catch are increasing, including anecdotal reports of bottlenose dolphins getting "snagged" (Rizzuto 2007). Interaction rates between dolphins and the NWHI bottomfish fishery were estimated based on studies conducted in 1990-1993, indicating that an average of 2.67 dolphin interactions, defined as incidence of dolphins removing bait or catch from hooks, occurred for every 1000 fish brought on board (Kobayashi & Kawamoto 1995) These interactions generally involved bottlenose dolphins and it is not known whether these interactions result in serious injury or mortality of dolphins. This fishery was observed from 2003 through 2005 at 18-25% coverage, during which time, no incidental takes of cetaceans were reported. The bottomfish fishery is no longer permitted for the Northwestern Hawaiian Islands.

Table 1. Summary of available information on incidental mortality and serious injury of bottlenose dolphins (Hawaii Pelagic stock) in commercial longline fisheries, within and outside of the U.S. EEZs (McCracken 2017). Mean annual takes are based on 2011-2015 data unless otherwise indicated. Information on all observed takes (T) and combined mortality events & serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome.

| Fishery Name | Year | Data Type | Percent Observer Coverage | Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of Hawaii Pelagic stock bottlenose dolphins | | | |
| | | | | Outside U.S. EEZs | | Hawaiian EEZ | |
				Obs. T/MSI	Estimated M&SI (CV)	Obs. T/MSI	Estimated M&SI (CV)
Hawaii-based deep-set longline fishery	2011	Observer data	20% / 22% / 21% / 21% / 20%	0	0 (-)	0	0 (-)
	2012		20%	0	0 (-)	0	0 (-)
	2013		20%	2/2	11 (0.6)	0	0 (-)
	2014		21%	0	0 (-)	0	0 (-)
	2015		21%	0	0 (-)	0	0 (-)
Mean Estimated Annual Take (CV)					**2.2 (0.9)**		**0 (-)**
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	2/1	1	0	0
	2012		100%	1/1	1	0	0
	2013		100%	2/2	2	0	0
	2014		100%	4/4	4	0	0
	2015		100%	2/2	2	0	0
Mean Annual Takes (100% coverage)					**2**		**0**
Minimum total annual takes within U.S. EEZ							**0 (-)**

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, 11 bottlenose dolphins were observed hooked or entangled in the SSLL fishery (100% observer coverage), and two bottlenose dolphins were observed taken in the DSLL fishery (20-22% observer coverage) (Bradford 2017, Bradford & Forney 2017, McCracken 2017). Based on the locations, these takes are all considered to have been from the Pelagic Stock of bottlenose dolphins. Ten of the 11 dolphins were considered to have been seriously injured (Bradford 2017, Bradford & Forney 2017), based on an evaluation of the observer's description of the interaction and following the most recently developed criteria for assessing serious injury

in marine mammals (NMFS 2012). Average 5-yr estimates of annual mortality and serious injury for the Pelagic Stock during 2011-2015 are 4.2 (CV = 0.9) bottlenose dolphins outside of U.S. EEZs, and 0 within the Hawaiian Islands EEZ (Table 1, McCracken 2017). Four unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been bottlenose dolphins.

KAUAI/NIIHAU STOCK
POPULATION SIZE
A photo-identification study conducted from 2003 to 2005 identified 102 individual bottlenose dolphins around Kauai and Niihau (Baird *et al.* 2009). A Lincoln-Peterson mark-recapture analysis of the photo-identification data resulted in an abundance estimate of 147 (CV=0.11), or 184 animals when corrected for the proportion of marked individuals (Baird *et al.* 2009). The CV of this estimate is likely negatively-biased, as it does not account for variation in the proportion of marked animals within groups. There is no current abundance estimate for this stock.

Minimum Population Estimate
The minimum population estimate for the Kauai/Niihau stock of bottlenose dolphins is the number of distinctive individuals identified during 2012 to 2015 photo-identification studies, or 97 dolphins (Baird *et al.* 2017). The data used in the 2003-2005 mark-recapture estimate (Baird *et al.* 2009) are considered outdated, and therefore are not suitable for deriving a minimum abundance estimate.

Current Population Trend
Only one abundance estimate is available for this stock, such that there is insufficient information to assess population trends.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES
No data are available on current or maximum net productivity rate for this species in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL
The potential biological removal (PBR) level for this stock is calculated as the minimum population size (97) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a stock of unknown status with no reported fishery mortality or serious injury within the Kauai/Niihau stock range; Wade & Angliss 1997), resulting in a PBR of 1.0 bottlenose dolphins per year.

STATUS OF STOCK
The Kauai/Niihau Stock of bottlenose dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of bottlenose dolphins in the Kauai/Niihau stock relative to OSP is unknown, and there are insufficient data to evaluate abundance trends. Bottlenose dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. There have been no reports of recent mortality or serious injuries; however, there is no systematic monitoring for interactions with protected species within near-shore fisheries that may take this species, thus mean annual takes are undetermined. Insufficient information is available to determine whether the total fishery mortality and serious injury for bottlenose dolphins is insignificant and approaching zero mortality and serious injury rate. One stranded bottlenose dolphin from the Kauaii/Niihau stock tested positive for *Morbillivirus* (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters (Jacob *et al.* 2016), raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

OAHU STOCK
POPULATION SIZE
A photo-identification study conducted in 2002, 2003 and 2006 identified 67 individual bottlenose dolphins around Oahu (Baird *et al.* 2009). A Lincoln-Peterson mark-recapture analysis of the photo-identification data resulted in an abundance estimate of 594 (CV=0.54), or 743 animals when corrected for the proportion of marked individuals (Baird *et al.* 2009). The estimate does not include individuals from the Northeastern (windward) side of the island. There is no current abundance estimate for this stock.

Minimum Population Estimate
There is no current minimum population estimate for the Oahu stock of bottlenose dolphins. The data used in the 2002-2006 mark-recapture estimate (Baird *et al.* 2009) are considered outdated, and therefore are not suitable

for deriving a minimum abundance estimate, and the number of distinctive individuals identified during 2009 to 2012 photo-identification studies (Baird *et al.* 2017) is derived from insufficient survey effort to be considered a reasonable estimate of minimum population size.

Current Population Trend

Only one abundance estimate is available for this stock, such that there is insufficient information to assess population trends.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for this species in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a stock of unknown status with no reported fishery mortality in the stock range (Wade and Angliss 1997). Because there is no minimum population size estimate for this stock, the PBR is undetermined.

STATUS OF STOCK

The Oahu stock of bottlenose dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of bottlenose dolphins in Oahu waters relative to OSP is unknown, and there are insufficient data to evaluate abundance trends. Bottlenose dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. There have been no reports of recent mortality or serious injuries; however, there is no systematic monitoring for interactions with protected species within near-shore fisheries that may take this species, thus mean annual takes are undetermined. Insufficient information is available to determine whether the total fishery mortality and serious injury for bottlenose dolphins is insignificant and approaching zero mortality and serious injury rate. *Morbilivirus* has been detected within other insular stocks of bottlenose dolphins in Hawaii (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

4-ISLANDS STOCK
POPULATION SIZE

A photo-identification study conducted from 2000-2006 identified 98 individual bottlenose dolphins around Maui and Lanai (Baird *et al.* 2009). A Lincoln-Peterson mark-recapture analysis of the photo-identification data resulted in an abundance estimate of 153 (CV=0.24), or 191 animals when corrected for the proportion of marked individuals (Baird *et al.* 2009). This abundance estimate likely underestimates the total number of bottlenose dolphins in the 4-islands region because it does not include individuals from the Northeastern (windward) sides of Maui and Molokai. The CV of this estimate is likely negatively-biased, as it does not account for variation in the proportion of marked animals within groups. There is no current abundance estimate for this stock.

Minimum Population Estimate

There is no current minimum population estimate for the 4-Islands stock of bottlenose dolphins. The data used in the 2000-2006 mark-recapture estimate (Baird *et al.* 2009) are considered outdated, and therefore are not suitable for deriving a minimum abundance estimate, and the number of distinctive individuals identified during 2009 to 2012 photo-identification studies (Baird *et al.* 2017) is derived from insufficient survey effort to be considered a reasonable estimate of minimum population size.

Current Population Trend

Only one abundance estimate is available for this stock, such that there is insufficient information to assess population trends.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for this species in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size

times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a stock of unknown status with no reported fishery mortality in the 4-Islands stock area (Wade and Angliss 1997). Because there is no minimum population size estimate for this stock, the PBR is undetermined.

STATUS OF STOCK

The 4-Islands Region Stock of bottlenose dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of bottlenose dolphins in 4-Islands waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Bottlenose dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor as "depleted" under the MMPA. There have been no reports of recent mortality or serious injuries of this stock; however, there is no systematic monitoring for interactions with protected species within near-shore fisheries that may take this species, thus mean annual takes are undetermined. Insufficient information is available to determine whether the total fishery mortality and serious injury for bottlenose dolphins is insignificant and approaching zero mortality and serious injury rate. *Morbilivirus* has been detected within other insular stocks of bottlenose dolphins in Hawaii (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

HAWAII ISLAND STOCK
POPULATION SIZE

A photo-identification study conducted from 2000-2006 identified 69 individual bottlenose dolphins around the island of Hawaii (Baird *et al.* 2009). A Lincoln-Peterson mark-recapture analysis of the photo-identification data resulted in an abundance estimate of 102 (CV=0.13), or 128 animals when corrected for the proportion of marked individuals (Baird *et al.* 2009). This abundance estimate likely underestimates the total number of bottlenose dolphins around the island of Hawaii because it does not include individuals from the Northeastern (windward) side of the island. The CV of this estimate is likely negatively-biased, as it does not account for variation in the proportion of marked animals within groups. There is no current abundance estimate for this stock.

Minimum Population Estimate

The minimum population estimate for the Hawaii Island bottlenose dolphins is the number of distinctive individuals identified during 2010 to 2013 photo-identification studies, or 91 dolphins (Baird *et al.* 2017). The data used in the 2000-2006 mark-recapture estimates (Baird *et al.* 2009) are considered outdated, and therefore are not suitable for deriving a minimum abundance estimate.

Current Population Trend

Only one abundance estimate is available for this stock, such that there is insufficient information to assess population trends.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for this species in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (91) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a stock of unknown status with no reported fishery mortality in the Hawaii Islands stock area (Wade and Angliss 1997), resulting in a PBR of 0.9 bottlenose dolphins per year.

STATUS OF STOCK

The Hawaii Island Stock of bottlenose dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of bottlenose dolphins in waters around Hawaii Island relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Hawaii Island bottlenose dolphins are regularly seen near aquaculture pens off the Kona coast, and aquaculture workers have been observed feeding bottlenose dolphins. Bottlenose dolphins in this region are also known to interact with divers. Bottlenose dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. In the past 5 years, one animal was partially disentangled by a diver, but with hook and line remaining in its mouth was considered a serious injury. There is no systematic monitoring of takes in near-shore fisheries that may take this species, the single observed serious injury may be an underestimate of the total fishery mortality for this

stock. Total fishery mortality and serious injury for Hawaii Island bottlenose dolphins is not approaching zero mortality and serious injury rate. *Morbilivirus* has been detected within other insular stocks of bottlenose dolphins in Hawaii (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

HAWAII PELAGIC STOCK
POPULATION SIZE
Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for bottlenose dolphins, resulting in an abundance estimate of 21,815 (CV = 0.57) bottlenose dolphins (Bradford *et al.* 2017) in the Hawaii pelagic stock. A 2002 shipboard line-transect survey of the same region resulted in a density estimate of 1.31 individuals per 1000 km^2, such that when applied to the Pelagic Stock area (waters beyond the 1000 m isobath, (see Figures 1-2), the stock-specific abundance for 2002 was estimated as 3,178 (CV=0.59). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data.

Minimum Population Estimate
The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al 1995) of the 2010 line-transect abundance estimate for the Hawaii Pelagic Stock, or 13,957 bottlenose dolphins.

Current Population Trend
Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES
No data are available on current or maximum net productivity rate for this species in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL
The potential biological removal (PBR) level for this stock is calculated as the minimum population size within the U.S EEZ of the Hawaiian Islands (13,957) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.5 (for a stock of unknown status with a Hawaiian Islands EEZ fishery mortality and serious injury rate CV of 0; Wade and Angliss 1997), resulting in a PBR of 140 bottlenose dolphin per year.

STATUS OF STOCK
The Hawaii Pelagic Stock of bottlenose dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of bottlenose dolphins in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. It is not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. The estimated rate of fisheries related mortality or serious injury within the Hawaiian Islands EEZ (0 animals per year) is less than the PBR (140). The total fishery mortality and serious injury for Hawaii pelagic bottlenose dolphins is insignificant and approaching zero mortality and serious injury rate. *Morbilivirus* has been detected within other insular stocks of bottlenose dolphins in Hawaii (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

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PANTROPICAL SPOTTED DOLPHIN (*Stenella attenuata attenuata*):
Hawaiian Islands Stock Complex – Oahu, 4-Islands, Hawaii Island, and Hawaii Pelagic Stocks

STOCK DEFINITION AND GEOGRAPHIC RANGE

Pantropical spotted dolphins are primarily found in tropical and subtropical waters worldwide (Perrin *et al.* 2009). Much of what is known about the species in the North Pacific has been learned from specimens obtained in the large directed fishery in Japan and in the eastern tropical Pacific (ETP) tuna purse-seine fishery (Perrin *et al*. 2009). Spotted dolphins are common and abundant throughout the Hawaiian archipelago, including nearshore where they are the second most frequently sighted species during nearshore surveys (Baird *et al*. 2013). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in 14 sightings in 2002 and 49 sightings in 2010 (Barlow 2006, Bradford *et al.* 2017; Figure 1). Morphological differences and distribution patterns indicate that the spotted dolphins around the Hawaiian Islands belong to a stock that is distinct from those in the ETP (Perrin 1975; Dizon *et al.* 1994; Perrin *et al*. 1994b).

Pantropical spotted dolphins have been observed in all months of the year around the main Hawaiian Islands, and in areas ranging from shallow near-shore water to depths of 5,000 m, although they peak in sighting rates in depths from 1,500 to 3,500 m (Baird *et al.* 2013). Although they represent from 22.9 to 26.5% of the odontocete sightings from Oahu, the 4-islands, and Hawaii Island, they are largely absent from the nearshore waters around Kauai and Niihau, representing only 3.9% of sightings in that area (Baird *et al.* 2013). Genetic analyses of 176 unique samples of pantropical spotted dolphins collected during near-shore surveys off each of the main Hawaiian Islands from 2002 to 2003, and near Hawaii Island from
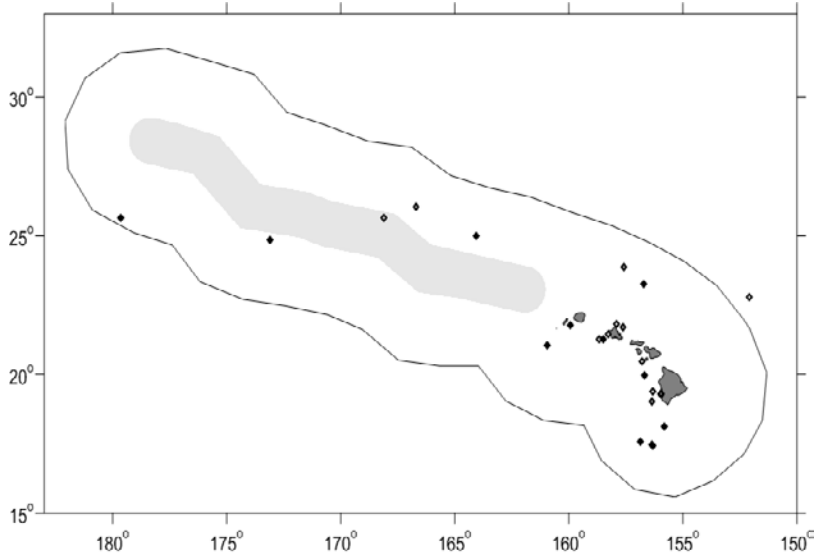
Figure 1. Pantropical spotted dolphin sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al*. 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath. Insular stock boundaries are shown in Figure 2.
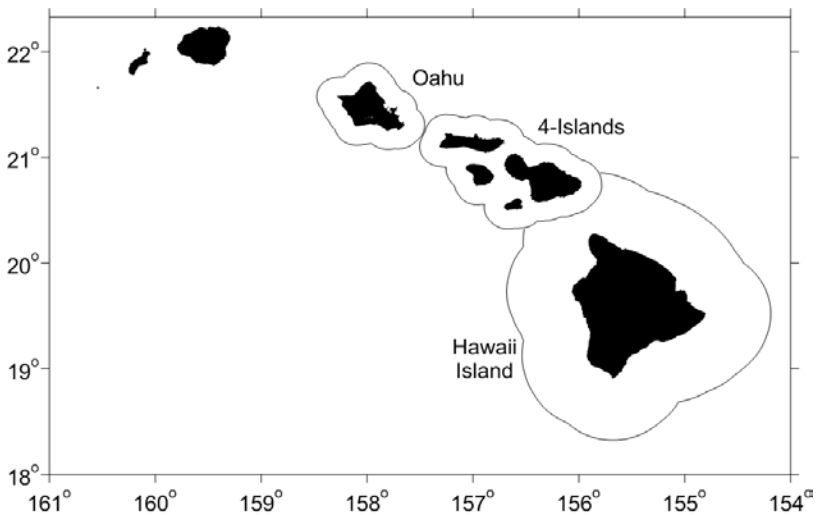
Figure 2. Main Hawaiian Islands insular spotted dolphin stock boundaries (gray lines). Oahu and 4-Islands stocks extend 20km from shore. Hawaii Island stock extends to 65km from shore based on distance of furthest encounter.

2005 through 2008 suggest three island-associated stocks are evident (Courbis *et al*. 2014). The results of the Courbis *et al*. (2014) study indicate that pantropical spotted dolphins in Hawaii's nearshore waters have low haplotypic diversity with haplotypes unique to each of the island areas. Courbis *et al*. (2014) conducted extensive tests on the relatedness of individuals among islands using the microsatellite dataset and found significant differences in haplotype frequencies between islands, suggesting genetic differentiation in spotted dolphins among islands. This suggestion is supported by the results of assignments tests, which indicate support for 3 island-associated populations: Hawaii Island, the 4-Islands region, and Oahu. Samples from Kauai and Niihau did not cluster together, but instead were spread among the Hawaii and Oahu clusters. Analysis of migration rate further support the separation of pantropical spotted dolphins into three island-associated stocks, with migration between regions on the order of a few individuals per generation. Based on an overview of all available information on pantropical spotted dolphins in Hawaiian waters, and NMFS guidelines for assessing marine mammal stocks (NMFS 2005), Oleson *et al.* (2013) proposed designation of three new island associated stocks in Hawaiian waters, as well as recognition of a fourth broadly distributed spotted dolphin stock given the frequency of sightings in pelagic waters. Fishery interactions with pantropical spotted dolphins and sightings near Palmyra and Johnston Atolls (NMFS PIR unpublished data) demonstrate that this species also occurs in U.S. EEZ waters there, but it is not known whether these animals are part of the Hawaiian population or are a separate stock or stocks of pantropical spotted dolphins.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, there are four Pacific management stocks within the Hawaiian Islands EEZ (Oleson *et al.* 2013): 1) the Oahu stock, which includes spotted dolphins within 20km of Oahu, 2) the 4-Island stock, which includes spotted dolphins within 20 km of Maui, Molokai, Lanai, and Kahoolawe collectively, 3) the Hawaii Island stock, which includes spotted dolphins found within 65km from Hawaii Island, and 4) the Hawaii pelagic stock, which includes spotted dolphins inhabiting the waters throughout the Hawaiian Islands EEZ, outside of the insular stock areas, but including adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of the Hawaii pelagic stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005). Spotted dolphins involved in eastern tropical Pacific tuna purse-seine fisheries are managed separately under the MMPA.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. Entanglement in gillnets and hooking or entanglement in various hook and line fisheries have been reported for small cetaceans in Hawaii (Nitta & Henderson, 1993). No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line or gillnet fisheries because these fisheries are not observed or monitored for protected species bycatch. Commercial and recreational troll fisherman have been observed "fishing" dolphins off the islands of Hawaii, Lanai, and Oahu, including spotted dolphins, in order to catch tuna associated with the animals (Courbis *et al*. 2009, Rizzuto 2007, Shallenberger 1981). Anecdotal reports from fisherman indicate that spotted dolphins are sometimes hooked (Rizzuto 1997) and photographs of dolphins suggest animals may be injured by both lines and propeller strikes (Baird unpublished data). In 2010 a spotted dolphin (4-Islands stock) was observed entangled in fishing line off Lanai, with several wraps of line around the body and peduncle and a constricting wrap around the dorsal fin (Bradford & Lyman 2015). In 2014, a spotted dolphin (Hawaii Island stock) was observed hooked above the jaw and trailing 8-10 feet of fishing line (Bradford and Lyman in review). Based on the information provided, both of these injuries are considered serious injuries. The responsible fishery is not known for either case.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no pantropical spotted dolphins were observed hooked or entangled in the SSLL fishery (100% observer coverage) or in the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). Four additional unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been spotted dolphins.

OAHU STOCK

POPULATION SIZE

The population size of the Oahu stock of spotted dolphins has not been estimated.

Minimum Population Estimate

There is no information on which to base a minimum population estimate of the Oahu stock of spotted dolphins.

Current Population Trend

No data are available on current population trend.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Oahu stock is calculated as the minimum population estimate times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a species of unknown status with no estimated fishery mortality or serious injury within the Oahu stock area; Wade and Angliss 1997). Because there is no minimum population estimate available the PBR for Oahu stock of spotted dolphins is undetermined.

STATUS OF STOCK

The Oahu stock of spotted dolphins is not considered a strategic stock under the MMPA. The status of Oahu spotted dolphins relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance for this stock. Spotted dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. There is no information with which to determine whether the total fishery mortality and serious injury for this stock is insignificant and approaching zero mortality and serious injury rate. *Morbilivirus* has been detected within other insular stocks of pantropical spotted dolphins in Hawaii (Jacob *et al*. 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

4-ISLANDS STOCK

POPULATION SIZE

The population size of 4-Islands stock of spotted dolphins has not been estimated.

Minimum Population Estimate

There is no information on which to base a minimum population estimate of the 4-Islands stock of spotted dolphins.

Current Population Trend

No data are available on current population trend.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the 4-Islands stock is calculated as the minimum population estimate times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a species of unknown status with no estimated fishery mortality or serious injury within the 4-

Islands stock area; Wade and Angliss 1997). Because there is no minimum population estimate available for this stock the PBR for 4-Islands stock of spotted dolphins is undetermined.

STATUS OF STOCK

The 4-Islands stock of spotted dolphins is not considered a strategic stock under the MMPA. The status of 4-Islands spotted dolphins relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance for this stock. Spotted dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. There are insufficient data are available to determine whether the total fishery mortality and serious injury for this stock is insignificant and approaching zero mortality and serious injury rate. *Morbilivirus* has been detected within other insular stocks of pantropical spotted dolphins in Hawaii (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

HAWAII ISLAND STOCK

POPULATION SIZE

The population size of the Hawaii Island stock of spotted dolphins has not been estimated. An extensive collection of identification photos from this population are available; however, a photo-identification catalog has not been developed. Such a catalog could serve as the basis for developing mark-recapture estimates, but no such analyses have yet been conducted.

Minimum Population Estimate

There is no information on which to base a minimum population estimate of the Hawaii Island stock of spotted dolphins.

Current Population Trend

No data are available on current population trend.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii Island stock is calculated as the minimum population estimate times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a species of unknown status with no estimated fishery mortality or serious injury within the Hawaii Island stock area; Wade and Angliss 1997). Because there is no minimum population estimate available for this stock the PBR for Hawaii Island stock of spotted dolphins is undetermined.

STATUS OF STOCK

The Hawaii Island stock of spotted dolphins is not considered a strategic stock under the MMPA. The status of Hawaii Island spotted dolphins relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance for this stock. Spotted dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Although one dolphin has been considered serious injured due to an interaction with fishing gear, there are insufficient data to determine whether the total fishery mortality and serious injury for this stock is insignificant and approaching zero mortality and serious injury rate. One spotted dolphin found stranded on Hawaii Island has tested positive for *Morbillivirus* (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters (Jacob 2012) raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

HAWAII PELAGIC STOCK

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for spotted dolphins, resulting in an abundance estimate of 55,795 (CV = 0.40) spotted dolphins (Bradford *et al.* 2017) in the Hawaii pelagic stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 8,978 (CV=0.48) pantropical spotted dolphins (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Population estimates are available for Japanese waters (Miyashita 1993), but it is not known whether any of these animals are part of the same population that occurs around the Hawaiian Islands.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate for the pelagic stock area or 40,338 pantropical spotted dolphins.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii pelagic pantropical spotted dolphin stock is calculated as the minimum population estimate within the U.S. EEZ of the Hawaiian Islands (40,338) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a species of unknown status with no known fishery mortality within the U.S. EEZ of the Hawaiian Islands; Wade and Angliss 1997), resulting in a PBR of 403 pantropical spotted dolphins per year.

STATUS OF STOCK

The Hawaii pelagic stock of spotted dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of Hawaii pelagic pantropical spotted dolphins relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Pantropical spotted dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries within U.S. EEZs, the total fishery mortality and serious injury can be considered to be insignificant and approaching zero. *Morbilivirus* has been detected within other insular stocks of bottlenose dolphins in Hawaii (Jacob *et al.* 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

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STRIPED DOLPHIN (*Stenella coeruleoalba*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Striped dolphins are found in tropical to warm-temperate waters throughout the world (Perrin et al. 2009). Sightings have historically been infrequent in nearshore waters (Shallenberger 1981, Mobley et al. 2000, Baird et al 2013). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands, resulted in 15 sightings of striped dolphins in 2002 and 29 in 2010 (Figure 1; Barlow 2006, Bradford et al. 2017).

Striped dolphins have been intensively exploited in the western North Pacific, where three migratory stocks are provisionally recognized (Kishiro and Kasuya 1993). In the eastern tropical Pacific all striped dolphins are provisionally considered to belong to a single stock (Dizon et al. 1994). There is insufficient data to examine finer stock structure within Hawaiian waters, though data available to date do not suggest island-associated populations for this species (Baird 2016).

For the Marine Mammal Protection

Figure 1. Striped dolphin sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford et al. 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument.

Act (MMPA) stock assessment reports, striped dolphins within the Pacific U.S. EEZ are divided into two discrete, non-contiguous areas: 1) waters off California, Oregon and Washington, and 2) waters around Hawaii (this report), including animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of the Hawaii stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005). Striped dolphins involved in eastern tropical Pacific tuna purse-seine fisheries are managed separately under the MMPA.

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for striped dolphins, resulting in an abundance estimate of 61,021 (CV = 0.38) striped dolphins (Bradford et al. 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 13,143 (CV=0.46) striped dolphins (Barlow 2006). Abundance analyses of the 2002 and 2010 datasets used different g(0) values. Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Population estimates are available for Japanese waters (Miyashita 1993) and the eastern tropical Pacific (Wade and Gerrodette 1993), but it is not known whether any of these animals are part of the same population that occurs around the Hawaiian Islands.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution
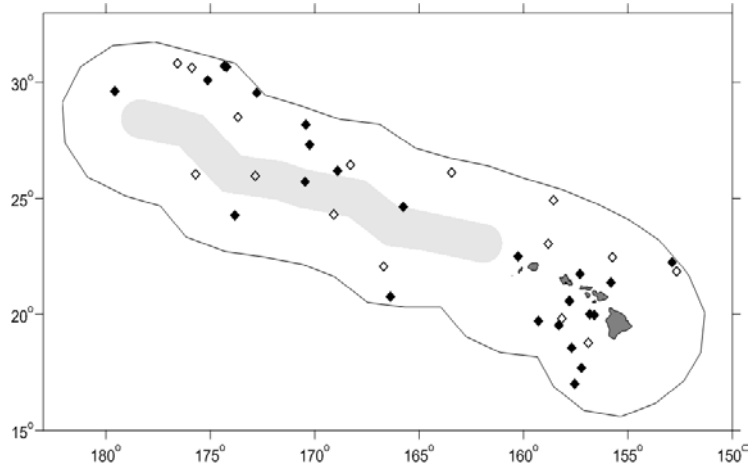
(Barlow et al 1995) of the 2010 abundance estimate, or 44,922 striped dolphins.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of striped dolphins is calculated as the minimum population size within the U.S. EEZ of the Hawaiian Islands (44,922) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.5 (for a stock of unknown status with no known fishery mortality and serious injury within the Hawaiian Islands EEZ; Wade and Angliss 1997), resulting in a PBR of 449 striped dolphins per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. Entanglement in gillnets and hooking or entanglement in various hook and line fisheries have been reported for small cetaceans in Hawaii (Nitta & Henderson, 1993). One striped dolphin stranded entangled in fishing gear in 2005, but the responsible fishery cannot be determined, as the entangled gear was not described (NMFS PIR MMRN). No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line or gillnet fisheries because these fisheries are not observed or monitored for protected species bycatch.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline

Figure 2. Locations of striped dolphin takes (filled diamonds) in Hawaii-based longline fisheries, 2011-2015. Solid lines represent the U.S. EEZs. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, one striped dolphin was seriously injured, one not seriously injured, and one could not be determined based on the information provided by the observer in the SSLL fishery (100% observer coverage), and one striped dolphin was killed and one not seriously injured in the DSLL fishery (20-21% observer coverage) (Figure 2, Bradford 2017, Bradford and Forney 2017, McCracken 2017). All striped dolphin interactions occurred outside of the U.S. EEZs. Average 5-yr estimates of annual mortality and serious injury for 2011-2015 are 1.7 (CV = 1.0) dolphins outside of U.S. EEZs, and zero within the Hawaiian Islands EEZ (Table 1). Four additional unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been striped dolphins.
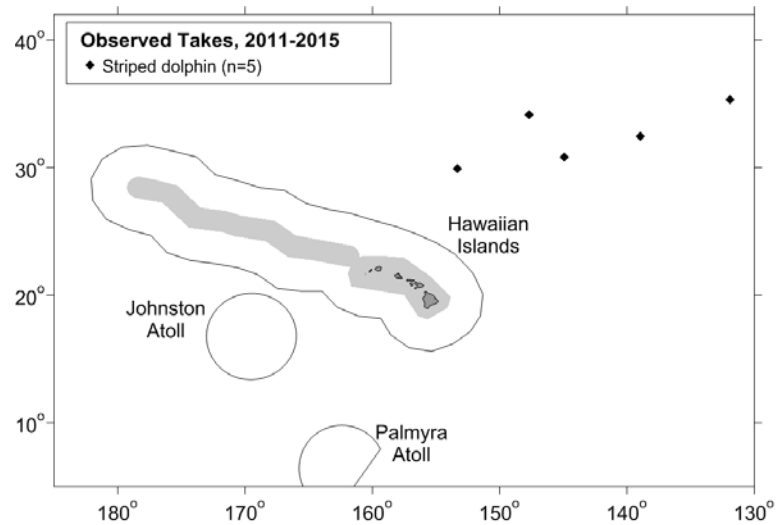
Table 1. Summary of available information on incidental mortality and serious injury of striped dolphin (Hawaii stock) in commercial longline fisheries, within and outside of U.S. EEZs (McCracken 2017). Mean annual takes are

based on 2011-2015 data unless otherwise indicated. Information on all observed takes (T) and combined mortality events & serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome.

Fishery Name	Year	Data Type	Percent Observer Coverage	Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of striped dolphins			
				Outside U.S. EEZs		Hawaiian EEZ	
				Obs. T/MSI	Estimated M&SI (CV)	Obs. T/MSI	Estimated M&SI (CV)
Hawaii-based deep-set longline fishery	2011	Observer data	20%	1/1	3 (0.8)	0	0 (-)
	2012		20%	0	0 (-)	0	0 (-)
	2013		20%	0	0 (-)	0	0 (-)
	2014		21%	0	0 (-)	0	0 (-)
	2015		21%	1/0	3 (1.1)	0	0 (-)
Mean Estimated Annual Take (CV)					1.1 (1.0)		0 (-)
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	0	0	0	0
	2012		100%	1/0	0	0	0
	0213		100%	0	0	0	0
	2014		100%	2/2[†]	2	0	0
	2015		100%	0	0	0	0
Mean Annual Takes (100% coverage)					0.6		0
Minimum total annual takes within U.S. EEZ							0 (-)

[†] Injury status could not be determined based on information collected by the observer. Injury status is prorated (see text).

STATUS OF STOCK

The Hawaii stock of striped dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of striped dolphins in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Striped dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries in U.S. EEZ waters, total fishery mortality and serious injury for striped dolphins can be considered insignificant and approaching zero. One striped dolphin stranded in the main Hawaiian Islands tested positive for *Brucella* (Chernov, 2010) and two for *Morbillivirus* (Jacob et al. 2016). *Brucella* is a bacterial infection that if common in the population may limit recruitment by compromising male and female reproductive systems, and can also cause neurological disorders that may result in death (Van Bressem et al. 2009). Although *morbillivus* is known to trigger lethal disease in cetaceans (Van Bressem et al. 2009), its impact on the health of the stranded animals is not known as it was found in only a one tested tissue within each animal (Jacob et al. 2016). The presence of *Morbillivirus* in 10 species (Jacob et al. 2016) and *Brucella* in 3 species (Cherbov 2010, West unpublished data) raises concerns about the history and prevalence of these diseases in Hawaii and the potential population impacts on Hawaiian cetaceans. It is not known if *Brucella or Morbillivirus* are common in the Hawaii stock.

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FRASER'S DOLPHIN (*Lagenodelphis hosei*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Fraser's dolphins are distributed worldwide in tropical waters (Dolar 2009 in Perrin et al. 2009). They have only recently been documented within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands, during a 2002 cetacean survey (Barlow 2006), and were seen 4 times during a similar 2010 survey (Bradford et al. 2017, Figure 1). There have been only 2 sightings of Fraser's dolphins during 13 years of nearshore surveys in the leeward main Hawaii Islands (Baird et al. 2013).

For the Marine Mammal Protection Act (MMPA) stock assessment reports, there is a single Pacific management stock including animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).
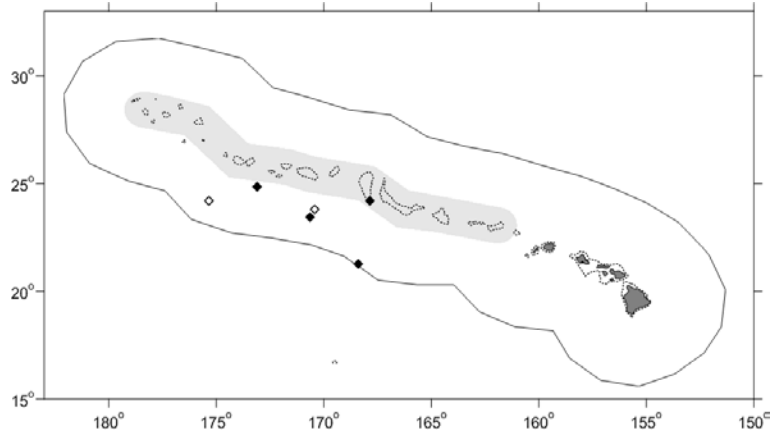
Figure 1. Fraser's dolphin sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard cetacean surveys of U.S. waters surrounding the Hawaiian Islands (Barlow 2006, Bradford et al 2017; see Appendix 2 for details on timing and location of survey effort). Outer line indicates approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for bottlenose dolphins, resulting in an abundance estimate of 51,491 (CV = 0.66) Fraser's dolphins (Bradford et al. 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 10,226 (CV=1.16) Fraser's dolphins (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Population estimates for Fraser's dolphins have been made in the eastern tropical Pacific (Wade and Gerrodette 1993), but it is not known whether these animals are part of the same population that occurs around the Hawaiian Islands and in the central North Pacific.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al 1995) of the 2010 abundance estimate or 31,034 Fraser's dolphins.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of Fraser's dolphin is calculated as the minimum population size within the U.S. EEZ of the Hawaiian Islands (13,034) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a stock of unknown status with no known fishery mortality or serious injury within the Hawaiian Islands EEZ; Wade and Angliss 1997), resulting in a PBR of 310 Fraser's dolphins per year.

HUMAN CAUSED MORTALITY AND SERIOUS INJURY
Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. No interactions between nearshore fisheries and Fraser's dolphins have been reported in Hawaiian waters.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 02015, no Fraser's dolphins were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). However, four unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been Fraser's dolphins.

STATUS OF STOCK

The Hawaii stock of Fraser's dolphins is not considered strategic under the 1994 amendments to the MMPA. The status of Fraser's dolphins in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. No habitat issues are known to be of concern for this stock. Fraser's dolphins are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries the total fishery mortality and serious injury can be considered to be insignificant and approaching zero.

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MELON-HEADED WHALE (*Peponocephala electra*):
Hawaiian Islands Stock Complex: Hawaiian Islands & Kohala Resident Stocks

STOCK DEFINITION AND GEOGRAPHIC RANGE

Melon-headed whales are found in tropical and warm-temperate waters throughout the world. The distribution of reported sightings suggests that the oceanic habitat of this species is primarily equatorial waters (Perryman *et al.* 1994). Small numbers have been taken in the tuna purse-seine fishery in the eastern tropical Pacific, and they are occasionally killed in direct fisheries in Japan and elsewhere in the western Pacific. Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands during 2002 and 2010 resulted in only one sighting each year (Figure 1; Barlow 2006, Bradford *et al.* 2017). Little is known about this species elsewhere in its range, and most knowledge about its biology comes from mass strandings (Perryman *et al.* 1994).

Photo-identification and telemetry studies suggest there are two demographically-independent populations of melon-headed whales in Hawaiian waters, the Hawaiian Islands stock and the Kohala resident stock. Resighting data and social

Figure 1. Melon-headed whale sighting location during the 2002 (open diamond) and 2010 (black diamond) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

network analyses of photographed individuals indicate very low rates of interchange between these populations (0.0009/yr) (Aschettino *et al.* 2012). This finding is supported by preliminary genetic analyses that suggest restricted gene flow between the Kohala residents and other melon-headed whales sampled in Hawaiian waters (Oleson *et al.* 2013). Some individuals in each population have been seen repeatedly for more than a decade, implying high site-fidelity for both populations. Individuals in the larger Hawaiian Islands stock have been resighted throughout the main Hawaiian Islands. Satellite telemetry data revealed distant offshore movements, nearly to the edge of the U.S. EEZ around the Hawaiian Islands (Figure 2), with apparent foraging near cold and warm-core eddies (Woodworth *et al.* 2012). Individuals in the smaller Kohala resident stock have a range restricted to shallower waters of the Kohala shelf and west side of Hawaii Island (Aschettino *et al.* 2012, Schorr *et al.* unpublished data). Satellite telemetry data indicate they occur in waters less than 2500m depth around the northwest and west shores of Hawaii Island, west of 156^0 45' W and north of 19^0 15'N (Oleson *et al.* 2013). The northern boundary between the two stocks provisionally runs through the Alenuihaha Channel between Hawaii Island and Maui, bisecting the distance between the 1000 m depth contours (Oleson *et al.* 2013).

For the Marine Mammal Protection Act (MMPA) stock assessment reports, there are two Pacific management stocks within the Hawaiian Islands EEZ (Oleson *et al.* 2013): 1) the Kohala resident stock, which includes melon-headed whales off the Kohala Peninsula and west coast of Hawaii Island and in less than 2500m of water, and 2) the Hawaiian Islands stock, which includes melon-headed whales inhabiting waters throughout the U.S. EEZ of the Hawaiian Islands, including the area of the Kohala resident stock, and adjacent high seas waters. At this time, assignment of individual melon-headed whales within the overlap area to either stock requires photographic-identification of the animal. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of the Hawaiian Islands stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).
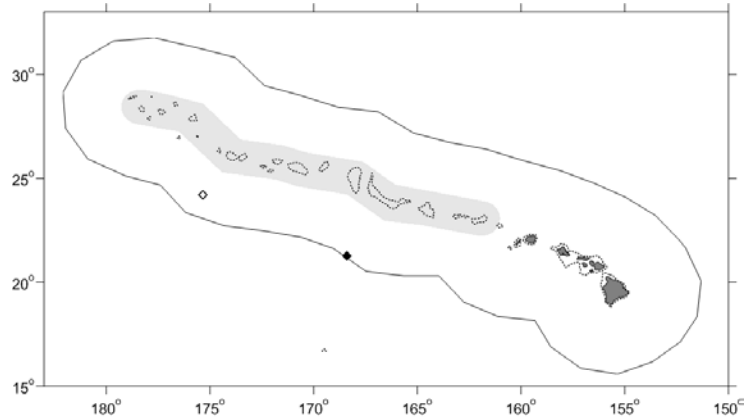
Figure 2. Sighting locations of melon-headed whales identified as being part of the Kohala resident stock (crosses) and telemetry records of Kohala resident (dark gray triangles) and Hawaiian Islands (light gray squares) melon-headed whale stocks (Schorr *et al.*, unpublished data). The dotted line around waters adjacent to the northwest and west shores of Hawaii Island represents the provisional stock boundary for the Kohala resident stock (Oleson *et al.*. 2013). The Kohala resident stock and the Hawaiian Islands stocks overlap throughout the range of the Kohala resident stock. Outer line represents U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in U.S. EEZ of the Hawaiian Islands waters is limited, but the gear types used in Hawaii fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. Entanglement in gillnets and hooking or entanglement in various hook and line fisheries have been reported for small cetaceans in Hawaii (Nitta & Henderson, 1993). No interactions between nearshore fisheries and melon-headed whales have been reported in Hawaiian waters. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line or gillnet fisheries because these fisheries are not observed or monitored for protected species bycatch. Long-term photo-identification studies have noted individuals from both the Kohala Resident and Hawaiian Islands stocks with bullet holes in their dorsal fin or with linear scars on their fins or bodies (Aschettino 2010) which may be consistent fisheries interactions.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no melon-headed whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). However, four unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been melon-headed whales.

Other Mortality

In recent years, there has been increasing concern that loud underwater sounds, such as active sonar and seismic operations, may be 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 may be impacted as well. A 2004 mass-stranding of 150-200 melon-headed whales in Hanalei Bay, Kauai occurred during a multi-national sonar training event around Hawaii (Southall *et al.*. 2006). Although data limitations regarding the position of the whales prior to their arrival in the Bay, the

magnitude of sonar exposure, behavioral responses of melon-headed whales to acoustic stimuli, and other possible relevant factors preclude a conclusive finding regarding the role of Navy sonar in triggering this event, sonar transmissions were considered a plausible cause of the mass stranding 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; Brownell *et al.*. 2009). In 2008 approximately 100 melon-headed whales stranded within a lagoon off Madagascar during high-frequency multi-beam sonar use by oil and gas companies surveying offshore. Although the multi-beam sonar cannot be conclusively deemed the cause of the stranding event, the very close temporal and spatial association and directed movement of the sonar use with the stranding event, the unusual nature of the stranding event, and that all other potential causal factors were considered unlikely to have contributed, an Independent Scientific Review panel found that multi-beam sonar transmissions were a "plausible, if not likely" contributing factor (Southall *et al.*. 2013) in this mass stranding event. This examination together with that of Brownell *et al.* (2009) suggests melon-headed whale may be particularly sensitive to impacts from anthropogenic sounds. No estimates of potential mortality or serious injury are available for U.S. waters.

KOHALA RESIDENT STOCK

POPULATION SIZE

Using the photo-ID catalog of individuals encountered between 2002 and 2009, Achettino (2010) used a POPAN open-population model to produce a mark-recapture abundance estimate of 447 (CV=0.12) individuals. A portion of the data used in that analysis is more than 8 years old; however, full sighting histories were required to produce a valid model for mark-recapture analyses, such that an estimate restricted to only the later years of the period is not available. Although this estimate includes individuals that have died since 2002 it is currently the best available abundance estimate for the resident stock.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.*. 1995) around the 2002-2009 mark-recapture abundance estimate (Aschettino 2010), or 404 melon-headed whales in the Kohala resident stock.

Current Population Trend

Photographic mark-recapture data will be evaluated in the future to assess whether sufficient data exists to assess trends.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population estimate (404) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a species of unknown status with no known fishery mortality; Wade and Angliss 1997), resulting in a PBR of 4.0 Kohala resident melon-headed whales per year.

STATUS OF STOCK

The Kohala resident stock of melon-headed whales is not considered strategic under the MMPA. The status of this stock relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Melon-headed whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. There have been no reports of recent mortality or serious injuries; however, there is no systematic monitoring of takes in near-shore fisheries that may take this species. Given noted bullet holes and potential line injuries on individuals from this stock, insufficient information is available to determine whether the total fishery mortality and serious injury for Kohala Resident melon-headed whales is insignificant and approaching zero mortality and serious injury rate. The very restricted range and small population size of Hawaii Island resident melon-headed whales suggests this population may be at risk due to its proximity to U.S. Navy training, including sonar transmissions, in the Alenuihaha Channel between Hawaii Island and Maui (Anonymous 2006). Although a 2004 mass-stranding in Hanalei Bay, Kauai could not be conclusively linked to

Naval training events in the region (Southall *et al.*. 2006), the spatiotemporal link between sonar exercises and the stranding does raise concern on the potential impact on the Kohala Resident population due to of sonar training nearby.

HAWAIIAN ISLANDS STOCK

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for bottlenose dolphins, resulting in an abundance estimate of 8,666 (CV = 1.00) melon headed whales (Bradford *et al.*. 2017) in the Hawaiian Islands stock. Using the photo-ID catalog of individuals encountered between 2002 and 2009 near the main Hawaiian Islands, Achettino (2010) used a POPAN open-population model to produce a mark-recapture abundance estimate of 5,794 (CV=0.20) individuals. A 2002 shipboard line-transect survey of the Hawaiian EEZ resulted in an abundance estimate of 2,950 (CV=1.17) melon-headed whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. An abundance estimate of melon-headed whales is available for the eastern tropical Pacific (Wade and Gerrodette 1993), but it is not known whether any of these animals are part of the same population that occurs around the Hawaiian Islands.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 line-transect abundance estimate (Bradford *et al.*. 2017) or 4,299 melon-headed whales. This log-normal 20th percentile minimum population size is similar to the log-normal 20th percentile mark-recapture estimate (4,904) from Aschettino (2010).

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population estimate for the U.S. EEZ of the Hawaiian Islands (4,299) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a species of unknown status with no known fishery mortality; Wade and Angliss 1997), resulting in a PBR of 43 melon-headed whales per year.

STATUS OF STOCK

The Hawaiian Islands stock of melon-headed whales is not considered strategic under the 1994 amendments to the MMPA. The status of this stock relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Melon-headed whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. There have been no reports of recent mortality or serious injuries; however, there is no systematic monitoring of takes in near-shore fisheries that may take this species. Given noted bullet holes and potential line injuries on individuals from this stock, insufficient information is available to determine whether the total fishery mortality and serious injury for Hawaiian Islands melon-headed whales is insignificant and approaching zero mortality and serious injury rate. A 2004 mass-stranding of melon-headed whales in Hanalei Bay, Kauai occurred during a multi-national sonar training event around Hawaii (Southall *et al.* 2006). Although the event could not be conclusively linked to Naval training events in the region (Southall *et al.* 2006), the spatiotemporal link between sonar exercises and the stranding does raise concern on the

potential impact on the Hawaiian Islands population due to its frequent use of nearshore areas within the main Hawaiian Islands.

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PYGMY KILLER WHALE (*Feresa attenuata*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Pygmy killer whales are found in tropical and subtropical waters throughout the world (Ross and Leatherwood 1994). They are poorly known in most parts of their range. Small numbers have been taken directly and incidentally in both the western and eastern Pacific. Most knowledge of this species is from stranded or live-captured specimens. Pryor et al. (1965) stated that pygmy killer whales have been observed several times off the lee shore of Oahu, and that "they seem to be regular residents of the Hawaiian area." More recently, pygmy killer whales have also been seen off the islands of Niihau and Lanai (McSweeney et al. 2009). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands, resulted in three sightings of pygmy killer whales in 2002 and five in 2010 (Figure 1; Barlow 2006, Bradford et al 2017).

Pygmy killer whales in Hawaiian waters may comprise more than one demographically-independent population.. A

Figure 1. Pygmy killer whale sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford et al. 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

22-year study off the Hawaii Island indicates that pygmy killer whales occur there year-round and in stable social groups. Over 80% of pygmy killer whales seen off Hawaii Island have been resighted and 92% have been linked into a single social network (McSweeney et al. 2009). Movements have also been documented between Hawaii Island and Oahu and between Oahu and Lanai (Baird et al. 2011a). Satellite telemetry data from four tagged pygmy killer whales suggest this resident group remains within 20km of shore (Baird et al 2011.a,b). Encounter rates for pygmy killer whales during near shore surveys are rare, representing less only 1.7% of all cetacean encounters to since 2000 (Baird et al. 2013). Division of this population into a separate island-associated stock may be warranted in the future.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, there is a single Pacific management stock including animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for pygmy killer whales, resulting in an abundance estimate of 10,640 (CV = 0.53) pygmy killer whales (Bradford et al. 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 956 (CV=0.83) pygmy killer whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. A population estimate has been made for this species in the eastern tropical Pacific (Wade and Gerrodette 1993), but it is not known whether any of these animals are part of the same population that occurs

around the Hawaiian Islands.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al 1995) of the 2010 abundance estimate or 6,998 pygmy killer whales within the Hawaiian EEZ.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for pygmy killer whales stock is calculated as the minimum population estimate for the U.S. EEZ of the Hawaiian Islands (6,998) times one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.4 (for a stock of unknown status with Hawaiian Islands EEZ fishery mortality and serious injury rate CV greater than 0.80; Wade and Angliss 1997), resulting in a PBR of 56 pygmy killer whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaii fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. Entanglement in gillnets and hooking or entanglement in various hook and line fisheries have been reported for small cetaceans in Hawaii (Nitta & Henderson, 1993). A stranded pygmy killer whale from Oahu showed signs of hooking injury (Schofield 2007) and mouthline injuries have also been noted in some individuals (Baird unpublished data), though it is not known if these interactions result in serious injury or mortality. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line or gillnet fisheries because these fisheries are not observed or monitored for protected species bycatch.

Figure 3. Location of an observed pygmy killer whale take (filled diamond) in the Hawaii-based longline fishery, 2011-2015. Solid lines represent the U. S. EEZ. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no pygmy killer whales were observed hooked or entangled in the SSLL fishery (100% observer coverage), and one pygmy killer whale was observed dead inside of the Hawaiian EEZ in the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). Average 5-yr estimates of annual mortality and serious injury for pygmy killer whales during 2011-2015 are 1.1 (CV = 1.1) pygmy killer whales within the Hawaiian Islands EEZ and 0 outside of U.S. EEZs

(Table 1, McCracken 2017). In addition, four unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been pygmy killer whales.

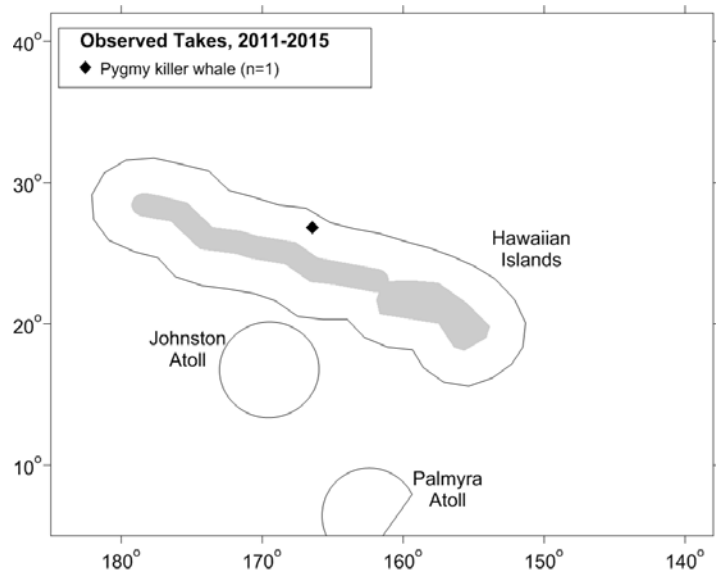**Table 1.** Summary of available information on incidental mortality and serious injury of pygmy killer whales in commercial longline fisheries, within and outside of the U.S. EEZs (McCracken 2017). Mean annual takes are based on 2011-2015 data unless otherwise indicated. Information on all observed takes (T) and combined mortality events & serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome.

Fishery Name	Year	Data Type	Percent Observer Coverage	Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of pygmy killer whales			
				Outside U.S. EEZs		Hawaiian EEZ	
				Obs. T/MSI	Estimated M&SI (CV)	Obs. T/MSI	Estimated M&SI (CV)
Hawaii-based deep-set longline fishery	2011	Observer data	20%	0	0 (-)	0	0 (-)
	2012		20%	0	0 (-)	0	0 (-)
	2013		20%	0	0 (-)	1/1	5 (0.9)
	2014		21%	0	0 (-)	0	0 (-)
	2015		21%	0	0 (-)	0	0 (-)
Mean Estimated Annual Take (CV)					**0 (-)**		**1.1 (1.1)**
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	3/3	0	0	0
	2012		100%	4/4	0	0	0
	2013		100%	3/2	0	0	0
	2014		100%	7/6	0	0	0
	2015		100%	4/3	0	0	0
Mean Annual Takes (100% coverage)					**0**		**0**
Minimum total annual takes within U.S. EEZ							**1.1 (1.1)**

Other Mortality

In recent years, there has been increasing concern that loud underwater sounds, such as active sonar and seismic operations, may be harmful to beaked whales (Cox et al. 2006) and other cetaceans, including melon-headed whales (Southall et al. 2006, 2013, Brownell et al. 2009) and pygmy killer whales (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 may be impacted as well. Two mass-strandings of pygmy killer whales occurred in the coastal areas of southwest Taiwan in February 2005, possibly associated with offshore naval training exercises (Wang and Yang 2006). A necropsy of one of the pygmy killer whales revealed hemorrhaging in the cranial tissues of the animal. Additional research on the behavioral response of delphinids in the presence of sonar transmissions is needed in order to understand the level of impact. No estimates of potential mortality or serious injury are available for U.S. waters.

STATUS OF STOCK

The Hawaii stock of pygmy killer whales is not considered strategic under the 1994 amendments to the MMPA. The status of pygmy killer whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Pygmy killer whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. The estimated rate of fisheries related mortality or serious injury within the Hawaiian Islands EEZ (1.1 animals per year) is less than the PBR (56). The total fishery mortality and serious injury can be considered to be insignificant and approaching zero because mortality and serious injury is less than 10% of PBR. One pygmy killer whale stranded in the MHI has tested positive for *Morbillivirus* (Jacob et al. 2016). The presence of *morbillivirus* in 10 species of cetacean in Hawaiian waters, all identified as a unique strain of *morbillivirus*, (Jacob et al. 2016), raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including cumulative impacts of disease with other stressors.

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FALSE KILLER WHALE (*Pseudorca crassidens*):
Hawaiian Islands Stock Complex – Main Hawaiian Islands Insular, Northwestern Hawaiian Islands, and Hawaii Pelagic Stocks

STOCK DEFINITION AND GEOGRAPHIC RANGE

False killer whales are found worldwide in tropical and warm-temperate waters (Stacey *et al.* 1994). In the North Pacific, this species is well known from southern Japan, Hawaii, and the eastern tropical Pacific. False killer whales were encountered during two shipboard line-transect surveys of the U.S. Exclusive Economic Zone (EEZ) around the Hawaiian Islands in 2002 and 2010 (Figure 1; Barlow 2006, Bradford *et al.* 2014) and focused studies near the main and Northwestern Hawaiian Islands indicate that false killer whales occur in near shore waters throughout the Hawaiian archipelago (Baird *et al.* 2008, 2013). This species also occurs in U.S. EEZ waters around Palmyra and Johnston Atolls (e.g., Barlow *et al.* 2008) and American Samoa (Johnston *et al.* 2008, Oleson 2009).

Genetic, photo-identification, and telemetry studies indicate there are three demographically-independent populations of false killer whales in Hawaiian waters. Genetic analyses indicate restricted gene flow between false killer whales sampled near the main Hawaiian Islands (MHI), the Northwestern Hawaiian Islands (NWHI), and in pelagic waters of the Eastern (ENP) and Central North Pacific (CNP) (Chivers *et al.* 2010; Martien *et al.* 2011,

Figure 1. False killer whale on-effort sighting locations during standardized shipboard surveys of the Hawaiian Islands U.S. EEZ (2002, gray diamond, Barlow 2006; 2010, black triangles, Bradford *et al.* 2014, pelagic waters of the central Pacific south of the Hawaiian Islands (2005, gray crosses, Barlow and Rankin 2007) and the Johnston Atoll EEZ. Outer dashed lines represent approximate boundary of U.S. EEZs; light shaded gray area is the main Hawaiian Islands insular false killer whale stock area, including overlap zone between MHI insular and pelagic false killer whale stocks; dark shaded gray area is the Northwestern Hawaiian Islands stock area, which overlaps the pelagic false killer whale stock area and part of the MHI insular false killer whale stock area. Detail of stock boundaries shown in Figure 2.

2014). Martien *et al.* (2014) analyzed mitochondrial DNA (mtDNA) control region sequences and genotypes from 16 nuclear DNA (nuDNA) microsatellite loci from 206 individuals from the MHI, NWHI, and offshore waters of the CNP and ENP and showed highly significant differentiation between populations confirming limited gene flow in both sexes. Their analysis using mtDNA reveals strong phylogeographic patterns consistent with local evolution of haplotypes unique to false killer whales occurring nearshore within the Hawaiian Archipelago and their assessment of nuDNA suggests that NWHI false killer whales are at least as differentiated from MHI animals as they are from offshore animals. Photographic–identification and social network analyses of individuals seen near the MHI indicate a tight social network with no connections to false killer whales seen near the NWHI or in offshore waters, and assessment of satellite telemetry collected from 27 tagged MHI false killer whales shows movements restricted to the MHI (Baird *et al.* 2010, 2012). Further evaluation of photographic and genetic data from individuals seen near the MHI suggests the occurrence of three separate social clusters (Baird *et al.* 2012, Martien *et al.* 2011), where mating occurs primarily, though not exclusively within clusters (Martien *et al.* 2011). Additional details on data and analyses supporting the separation of false killer whales in Hawaiian waters into three separate stocks are summarized within Oleson *et al.* (2010, 2012).
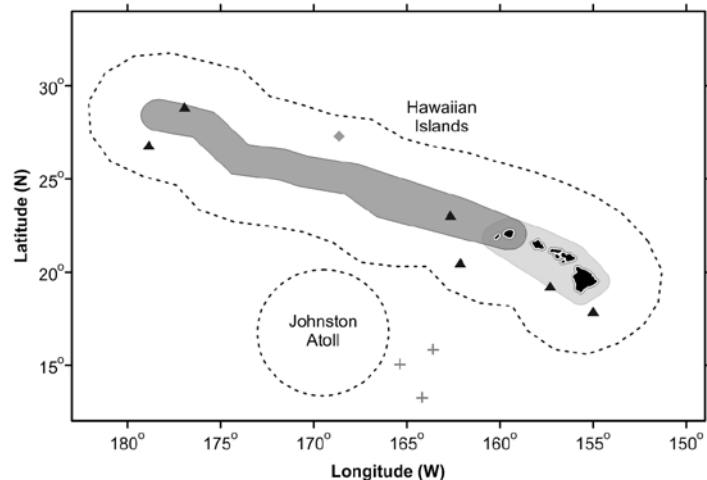
Figure 2. Sighting, biopsy sample, and telemetry record locations of false killer whale identified as being part of the MHI insular (square symbols), NWHI (triangle symbols), or pelagic (circle symbols) stocks. The MHI stock area is shown in light gray; the NWHI stock area is shown in dark gray; the pelagic stock area includes the entire EEZ excluding the region delineated by the black line around each of the MHI (reproduced from Bradford *et al.* 2015). The MHI insular, pelagic, and NWHI stocks overlap around Kauai and Niihau.

Fishery observers have collected tissue samples for genetic analysis from cetaceans incidentally caught in the Hawaii-based longline fishery since 2003. Between 2003 and 2010, eight false killer whale samples, four collected outside the Hawaiian EEZ and four collected within the EEZ but more than 100 nautical miles (185km) from the main Hawaiian Islands were determined to have Pacific pelagic haplotypes (Chivers *et al.* 2010). At the broadest scale, significant differences in both mtDNA and nuDNA are evident between pelagic false killer whales in the ENP and CNP strata (Chivers *et al.* 2010), although the sample distribution to the east and west of Hawaii is insufficient to determine whether the sampled strata represent one or more stocks, and where pelagic stock boundaries would be drawn.

The stock range and boundaries of the three Hawaiian stocks of false killer whales were recently reevaluated, given significant new information on the occurrence and movements of each stock and are reviewed in detail in Bradford *et al.* (2015) and shown in Figure 2. The stocks have partially overlapping ranges. MHI insular false killer whales have been satellite tracked as far as 115 km from the main Hawaiian Islands, while pelagic stock animals have been tracked to within 11 km of the main Hawaiian Islands and throughout the NWHI. NWHI false killer whales have been seen as far as 93 km from the NWHI and near-shore around Kauai and Oahu (Baird *et al.* 2012, Bradford *et al.* 2015). Stock boundary descriptions are complex, but can be summarized as follows. The MHI insular stock boundary is derived from a Minimum Convex Polygon (MCP) bounded around a 72-km radius of the MHI, resulting in a boundary shape that reflects greater offshore use in the leeward portion of the MHI. The NWHI stock boundary is defined by a 93-km radius around the NWHI, with this radial boundary extended to the southeast to encompass Kauai and Niihau. The NWHI boundary is latitudinally expanded at the eastern end of the NWHI to encompass animal movements observed outside of the 93-km radius (see Figure 2). The pelagic stock has no outer boundary. Throughout the MHI the pelagic stock inner boundary is placed at 11 km from shore. There is no inner boundary within the NWHI. The construction of these stock boundaries results in a number of stock overlap zones. The waters outside of 11km from shore from Oahu to Hawaii Island out to the MHI insular stock boundary are an overlap zone between the MHI insular and pelagic stocks. The entirety of the NWHI stock range, with the exception of the area within 11km around Kauai and Niihau is an overlap zone between NWHI and pelagic false killer whales. All three stocks overlap between 11 km from shore around Kauai and Niihau out to the MHI insular stock boundary

between Kauai and Nihoa and to the NWHI stock boundary between Kauai and Oahu (see Figure 2).

The pelagic stock includes animals found within the Hawaiian Islands EEZ and in adjacent international waters; however, because data on false killer whale abundance, distribution, and human-caused impacts are largely lacking for international waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005). The Palmyra Atoll stock of false killer whales is still considered to be a separate stock because comparisons amongst false killer whales sampled at Palmyra Atoll and those sampled from the MHI insular stock and the pelagic ENP reveal restricted gene flow, although the sample size remains too low for robust comparisons (Chivers *et al.* 2010). NMFS will obtain and analyze additional samples for genetic studies of Hawaii pelagic and Palmyra stock structure, and will evaluate new information on stock ranges as it becomes available.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, there are currently five Pacific Islands Region management stocks : 1) the Main Hawaiian Islands insular stock, which includes animals inhabiting waters within a modified 72km radius around the main Hawaiian Islands, 2) the Northwestern Hawaiian Islands stock, which includes animals inhabiting waters within a 93-km radius around the NWHI and Kauai, with a slight latitudinal expansion of this area at the eastern end of the range, 3) the Hawaii pelagic stock, which includes false killer whales inhabiting waters greater than 11 km from the main Hawaiian Islands, including adjacent high seas waters, 4) the Palmyra Atoll stock, which includes animals found within the U.S. EEZ of Palmyra Atoll, and 5) the American Samoa stock, which includes animals found within the U.S. EEZ of American Samoa. Estimates of abundance, potential biological removal, and status determinations for the first three stocks are presented below; the Palmyra Atoll and American Samoa stocks are covered in separate reports.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Interactions with false killer whales, including depredation of catch of a variety of pelagic fishes, have been identified in logbooks and NMFS observer records from Hawaii pelagic longline fishing trips (Nitta and Henderson 1993, Oleson *et al.* 2010, PIRO 2015). False killer whales have been observed feeding on mahi mahi, *Coryphaena hippurus*, and yellowfin tuna, *Thunnus albacares* (Baird 2009), and they have been reported to take large fish from the trolling lines of commercial and recreational fishermen (Shallenberger 1981). There are anecdotal reports of marine mammal interactions in the commercial Hawaii shortline fishery which sets gear at Cross Seamount and possibly around the main Hawaiian Islands. The commercial shortline fishery is licensed to sell their catch through the State of Hawaii Commercial Marine License program, and until recently, no reporting systems existed to document marine mammal interactions. Baird and Gorgone (2005) documented high rates of dorsal fin disfigurements consistent with injuries from unidentified fishing line for false killer whales belonging to the MHI insular stock. A recent report included evaluation of additional individuals with dorsal fin injuries and suggested that the rate of interaction between false killer whales and various forms of hook and line gear may vary by population and social cluster, with the MHI insular stock showing the highest rate of dorsal fin disfigurements (Baird *et al.* 2014). The commercial or recreational fishery or fisheries responsible for these injuries is unknown. Examination of a stranded MHI insular false killer whale in October 2013 revealed that this individual had five fishing hooks and fishing line in its stomach (NMFS PIR Marine Mammal Response Network). Although the fishing gear is not believed to have caused the death of the whale, the finding confirms that MHI insular false killer whales are consuming previously hooked fish or are interacting with hook and line fisheries in the MHI. Many 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 near-shore fisheries. No estimates of human-caused mortality or serious injury are currently available for near-shore hook and line or other fisheries because these fisheries are not observed or monitored for protected species bycatch.

Because of high rates of false killer whale mortality and serious injury in Hawaii-based longline fisheries, a Take Reduction Team was established in January 2010 (75 FR 2853, 19 January, 2010). The Team was charged with developing recommendations to reduce incidental mortality and serious injury of the Hawaii pelagic, MHI insular and Palmyra stocks of false killer whales in Hawaii-based longline fisheries. The Team submitted a draft Take Reduction Plan (TRP) to NMFS, and NMFS published a final TRP based on the Team's recommendations (77 FR 71260, 29 November, 2012). Take reduction measures include gear requirements, time-area closures, and measures to improve captain and crew response to hooked and entangled false killer whales. The seasonal contraction of the Longline Exclusion Zone (LLEZ) around the MHI was also eliminated. The TRP became effective December 31, 2012, with gear requirements effective February 27, 2013. These measures were not in effect during 2008-2012, a portion of the period for which bycatch was estimated in this report. Adjustments to bycatch estimation methods were implemented for 2013 to account for changes in fishing gear and captain training intended to reduce the false killer whale serious injury rate (see below, McCracken 2015).

There are two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas, but are prohibited from operating within the Papahānaumokuākea Marine National Monument (PMNM) and within the LLEZ around the main Hawaiian Islands. The PMNM originally included the waters within a 50 nmi radius around the NWHI. As of August, 2016, the PMNM area was expanded to extend to the 200 nmi EEZ boundary west of 163° W. Stock Assessment Reports generally describe fishery interaction details for the most recent five years, and as such, only years 2011 through 2015 are described here. Between 2011 and 2015, three false killer whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) within the U.S. EEZ of the Hawaiian Islands, and 26 false killer whales were observed taken in the DSLL fishery (20-21% observer

Figure 3. Locations of observed false killer whale takes (black symbols) and possible takes (blackfish) of this species (open symbols) in the Hawaii-based longline fisheries, 2011-2015. Takes occurring prior to the implementation of Take-Reduction Plan (2010-2012) regulations are shown as diamonds, and those since the TRP regulations (2013-2015) are shown as stars. Some take locations overlap. Solid gray lines represent the U.S. EEZ; the dotted line is the MHI insular stock area; the dashed line is the NWHI stock area; both MHI and NWHI stocks overlap with the pelagic stock. The gray shaded area represents the longline exclusion zone, implemented year-round since December 31, 2012, and original boundary of the Papahānaumokuākea Marine National Monument. Both areas were closed to longline fishing during the 2011-2015 period.

coverage) within Hawaiian waters or adjacent high-seas waters (excluding Palmyra Atoll EEZ waters) (Bradford 2017, Bradford and Forney 2017). The severity of injuries resulting from interactions with longline gear is determined based on an evaluation of the observer's description of each interaction and following the most recently developed criteria for assessing serious injury in marine mammals (NMFS 2012). Of the three animals taken in the SSLL fishery, two were considered not seriously injured and one could not be determined based on the information provided by the observer. In the DSLL fishery, 9 false killer whales were taken within the Hawaiian EEZ. Two of those takes occurred in 2012 within the pelagic-NWHI overlap zone north of Kauai before this area was closed to longline fishing. Of the remaining 7 interactions within the Hawaiian EEZ, all were within the range of the pelagic stock, with four considered seriously injured, and three could not be determined based on the information provided by the observer. Outside of the Hawaii EEZ, one was observed dead, 12 were considered seriously injured, and four were considered not seriously injured. Five additional unidentified "blackfish" (unidentified cetaceans known to be either false killer whales or short-finned pilot whales) were also taken, one within the SSLL fishery and four in the DSLL fishery. The single SSLL interaction occurred outside the Hawaiian EEZ and the animal was considered seriously injured. Of the four DSLL interactions, one occurred inside the Hawaii EEZ and was considered seriously injured, and three occurred outside the Hawaii EEZ, with one considered seriously injured, one considered not seriously injured, and one whose injury status could not be determined based on the information provided by the observer.

The injury status of estimated takes is prorated to serious versus non-serious using the historic rate of serious injury within the observed takes. For the period 2008 to 2012, the rate of serious injury for false killer whales was 93% (McCracken 2014). Because the implementation of weak hooks under the TRP was intended to reduce the serious injury rate in the deep-set fishery, these historic averages were not used for 2013-2015. The allocation of estimated serious versus non-serious injuries in 2013-2015 take was based on the proportion of serious versus non-serious injuries of observed takes in those years (McCracken 2017). The proration of serious injury status will be updated as additional data become available to better estimate serious versus non-serious injury proportion under TRP measures.
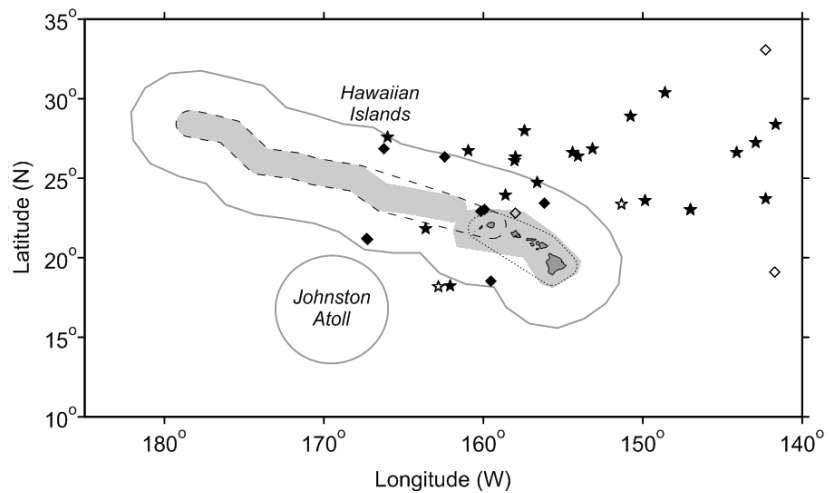
Table 1. Summary of available information on incidental mortality and serious injury (MSI) of false killer whales and unidentified blackfish (false killer whale or short-finned pilot whale) in commercial longline fisheries, by stock and EEZ area, as applicable (McCracken 2017). 5-yr mean annual takes are presented for 2008-2012, prior to the implementation of the TRP, for 2013-2015 due to changes in fishing gear under the TRP intended to reduce serious injury rate, and for 2011-2015, ignoring any change in mortality rate. Information on all observed takes (T) and combined mortality & serious injury is included. Unidentified blackfish are pro-rated as either false killer whales or short-finned pilot whales according to their distance from shore (McCracken 2010). CVs are estimated based on the combined variances of annual false killer whale and blackfish take estimates and the relative density estimates for each stock within the overlap zones. Values of '0' presented with no further precision are based on observation at 100% coverage and are not estimates.

Fishery Name	Year	Data Type	Percent Observer Coverage	Observed takes FKW T/MSI UB T/MSI Outside U.S EEZ	Within Hawaii EEZ	Estimated M&SI (CV) Pelagic Stock Outside U.S EEZ	Within Hawaii EEZ	MHI insular Stock	NWHI Stock
Hawaii-based deep-set longline fishery	2011	Observer data	20%	0 1/0	3/3[†] 1/1	2.2 (3.6)	12.2 (0.4)	0.1 (0.6)	0.3 (1.2)
	2012		20%	0 1/1	3/3*[†] 0	3.6 (2.3)	13.0 (0.4)	0.1 (3.9)	1.6 (1.3)
	2013		20%	3/1 0	1/1 0	6.6 (0.9)	4.1 (1.4)	0.0 (1.9)	0.0 (-)
	2014		21%	9/8 0	2/1[†] 0	35.8 (0.5)	8.4 (0.7)	0.0 (0.8)	0.0 (1.5)
	2015		21%	5/4 1/1[†]	0 0	22.1 (0.4)	0 (-)	0 (-)	0 (-)
Pre-TRP Mean Estimated Annual Take (CV) 2008-2012						**10.0 (0.4)**	**13.3 (0.2)**	**0.2 (0.4)**	**0.6 (0.8)**
Estimated Annual Take (CV) under TRP 2013-2015						**21.2 (0.5)**	**4.1 (1.0)**	**0.0 (0.7)**	**0.0 (1.3)**
Mean Estimated Annual Take (CV) 2011-2015						**15.2 (0.3)**	**7.5 (0.3)**	**-**	**0.4 (1.1)**
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	0 1/1	1/0 0	0.7	0	0	0
	2012		100%	0 0	1/1[†] 0	0	0.3	0	0
	2013		100%	0 0	0 0	0	0	0	0
	2014		100%	0 0	1/0 0	0	0	0	0
	2015		100%	0 0	0 0	0	0	0	0
Mean Annual Takes (100% coverage) 2008-2012						**0.3**	**0.3**	**0**	**0**
Mean Annual Take (CV) under TRP 2013-2015						**0**	**0**	**0**	**0**
Mean Annual Takes (100% coverage) 2011-2015						**0.1**	**0.1**	**-**	**0**
Pre-TRP Minimum total annual takes within U.S. EEZ (2008-2012)						**13.6 (0.2)**		**0.2 (0.4)**	**0.6 (0.8)**
Minimum total take under TRP within U.S. EEZ 2013-2015						**4.1 (1.0)**		**0 (0.7)**	**0 (1.3)**
Minimum total annual takes within U.S EEZ (2011-2015)						**7.6 (0.3)**		**-**	**0.4 (1.1)**

* Two observed takes occurred within the NWHI-pelagic overlap zone and are therefore allocated for proration between NWHI and pelagic stocks. Remaining estimated takes are prorated among stocks as described for each overlap zone.

[†] Injury status could not be determined based on information collected by the observer. Injury status is prorated (see text).

- Significant regulatory change under the TRP largely excluded the longline fishery from the MHI insular stock range, such that the 5-year average take is not reported for this stock.

Takes of false killer whales of unknown stock within the stock overlap zones must be prorated to MHI insular, pelagic, or NWHI stocks. No genetic samples are available to establish stock identity for the two takes inside the NWHI-pelagic overlap zone north of Kauai, but both stocks are considered at risk of interacting with longline gear. The pelagic stock is known to interact with longline fisheries in waters offshore of the overlap zone, based on two genetic samples obtained by fishery observers (Chivers *et al.* 2010). MHI insular and NWHI false killer whales have been documented via telemetry to move far enough offshore to reach longline fishing areas (Bradford *et al.* 2015), and animals from the MHI insular stock have a high rate of dorsal fin disfigurements consistent with injuries from unidentified fishing line (Baird and Gorgone 2005, Baird *et al.* 2014). 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, Hawaii 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 Hawaii 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.

Based on this approach, estimates of annual mortality and serious injury of false killer whales, by stock and EEZ area, are shown in Table 1. Three mortality and serious injury estimates are provided (Table 1): a 5-yr average for the period prior to TRP-implementation (2008-2012), a 3-yr average for the period following TRP implementation (2013-2015), and a 5-yr average for the most recent 5 years assuming no significant change in mortality rate within the fishery (2011-2015). The later estimate is not provided for the MHI insular stock as the fishery has been largely excluded from the stock range through expansion of the LLEZ, resulting in significant change in the conduct of the fishery with respect to this stock. The bycatch rate (per 1000 sets) and the proportion of non-serious injuries prior to and following TRP implementation were examined for all stocks as part of the FKW TRT monitoring strategy.

Proration of false killer whale takes within the overlap zones and of unidentified blackfish takes introduces unquantified uncertainty into the bycatch estimates, but until methods of determining stock identity for animals observed taken within the overlap zone are available, and all animals taken can be identified to species (e.g., photos, tissue samples), these proration approaches are needed ensure that potential impacts to all stocks are assessed in the overlap zones.

MAIN HAWAIIAN ISLANDS INSULAR STOCK

POPULATION SIZE

Bradford *et al.* 2018 used encounter data from dedicated and opportunistic surveys for MHI insular false killer whales 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 insular false killer whales 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 (CV = 0.14). Annual estimates over the 16 year survey period ranged from 144 to 187 animals and are similar to multi-year aggregated estimates published previously (e.g. Oleson *et al.* 2010).

Minimum Population Estimate

The minimum population estimate for the MHI insular stock of false killer whales 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 in review), or 149 false killer whales.

Current Population Trend

Reeves *et al.* (2009) suggested that the MHI insular stock of false killer whales may have declined during the last two decades, based on sightings data collected near Hawaii using various methods between 1989 and 2007. Baird (2009) reviewed trends in sighting rates of false killer whales from aerial surveys conducted using consistent methodology around the main Hawaiian Islands between 1994 and 2003 (Mobley *et al.* 2000). Sighting rates during these surveys showed a statistically significant decline that could not be attributed to any weather or methodological changes. The Status Review of MHI insular false killer whales (Oleson *et al.* 2010) presented a quantitative analysis of extinction risk using a Population Viability Analysis (PVA). The modeling exercise was conducted to evaluate the probability of actual or near extinction, defined as a population reduced to fewer than 20 animals, given measured, estimated, or inferred information on population size and trends, and varying impacts of catastrophes, environmental stochasticity and Allee effects. All plausible models indicated the probability of decline to fewer than 20 animals within 75 years was greater than 20%. Though causation was not evaluated, all plausible models indicated the population has declined since 1989, at an average rate of -9% per year (95% probability intervals -5% to -12.5%), though some two-stage models suggested a lower rate of decline over the past decade (Oleson *et al.* 2010). The annual abundance estimates available in Bradford *et al.* 2018 are not appropriate for evaluating population trends, as the study are varied by year, and each annual estimate represents only the animals present in the study area within that year.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for this species in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the MHI insular false killer whale stock is calculated as the minimum population estimate (149) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.1 (for a stock listed as Endangered under the ESA and with minimum population size less than 1500 individuals; Taylor *et al.* 2000) resulting in a PBR of 0.3 false killer whales per year, or approximately one animal every 3.3 years.

STATUS OF STOCK

The status of MHI insular stock false killer whales relative to OSP is unknown, although this stock appears to have declined during the past two decades (Oleson *et al.* 2010, Reeves *et al.* 2009; Baird 2009). MHI insular false killer whales are listed as "endangered" under the Endangered Species Act (1973) (77 FR 70915, 28 November, 2012). The Status Review report produced by the Biological Review Team (BRT) (Oleson *et al.* 2010, amended in Oleson *et al.* 2012) found that Hawaiian insular false killer whales are a Distinct Population Segment (DPS) of the global false killer whale taxon. Of the 29 identified threats to the population, the BRT considered the effects of small population size, including inbreeding depression and Allee effects, exposure to environmental contaminants (Ylitalo *et al.* 2009), competition for food with commercial fisheries (Boggs & Ito, 1993, Reeves *et al.* 2009), and hooking, entanglement, or intentional harm by fishermen to be the most substantial threats to the population. Because MHI insular false killer whales are formally listed as "endangered" under the ESA, they are automatically considered as a "depleted" and "strategic" stock under the MMPA. For the 5-yr period prior to the implementation of the TRP, the average estimated mortality and serious injury to MHI insular stock false killer whales (0.21 animals per year) exceeded the PBR (0.18 animals per year. Following implementation of the TRP a significant portion of the recognized stock range is inside of the expanded year-round LLEZ around the MHI, providing significant protection for this stock from longline fishing. Prior to that time, a seasonal contraction to the LLEZ potentially exposed a significant portion of the offshore range of the stock to longline fishing. Because of the significant change in longline fishery activity relative to the MHI insular stock under the TRP, the status of the stock is assessed relative to the post-TRP period (2013-2015). For this period the estimate of mortality and serious injury (0.01) is below the PBR (0.30). The total fishery mortality and serious injury for the MHI insular stock of false killer whales cannot be considered to be insignificant and approaching zero, as it is greater than 10% of PBR. Effects of other threats have yet to be assessed, e.g., nearshore hook and line fishing and environmental contamination. There is significant geographic overlap between various nearshore fisheries and evidence of interactions with hook-and-line gear (e.g. Baird *et al.* 2015), such that these fisheries may pose a threat to the stock. Five MHI insular false killer whales have recently stranded, including four from cluster 3 (PIRO MMRN), a high rate for a single social cluster. Recent research has indicated that concentrations of polychlorinated biphenyls (PCBs) exceeded proposed threshold levels for health effects in 84% of sampled MHI insular false killer whales (Foltz *et al.* 2014).

HAWAII PELAGIC STOCK

POPULATION SIZE

Analysis of a 2010shipboard line-transect survey the Hawaiian Islands resulted in an abundance estimate of 1,540 (CV=0.66) false killer whales outside of 11 km of the main Hawaiian Islands (Bradford *et al.* 2014, 2015). Bradford *et al.* (2014) reported that most (64%) false killer whale groups seen during the 2010 HICEAS survey were seen moving toward the vessel when detected by the visual observers. Together with an increase in sightings close to the trackline, these behavioral data suggest vessel attraction is likely occurring and may be significant. Although Bradford *et al.* (2014, 2015) employed a half-normal model to minimize the effect of vessel attraction, the abundance estimate may still be positively biased as a result of vessel attraction because groups originally outside of the survey strip, and therefore unavailable for observation by the visual survey team, may have moved within the survey strip and been sighted. There is some suggestion of such attractive movement within the acoustic data and visual data (Bradford *et al.* 2014), though the extent of any bias created by this movement is unknown. EEZ-wide abundance was previously estimated to be 484 (CV = 0.93) from a 2002 survey (Barlow and Rankin 2007). A 2005 survey (Barlow and Rankin 2007) resulted in a separate abundance estimate of 906 (CV=0.68) false killer whales in international waters south of the Hawaiian Islands EEZ and within the EEZ of Johnston Atoll, but it is unknown how many of these animals might belong to the Hawaii pelagic stock.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate for the Hawaiian Islands EEZ outside of 11 km from the main Hawaiian Islands (Bradford *et al.* 2014, 2015) or 928 false killer whales.

Current Population Trend

No data are available on current population trend. It is incorrect to conclude that the increase in the abundance estimate from 2002 to 2010 represents an increase in population size, given changes to the survey design in 2010 and the analytical framework specifically intended to better enumerate and account for overall group size (Bradford *et al.* 2014), the low precision of each estimate, and a lack of understanding of the oceanographic processes that may drive the distribution of this stock over time. Further, estimation of the detection function for the 2002 and 2010 estimates relied on shared data, such that the resulting abundance estimates are not statistically independent and cannot be compared in standard statistical tests. Only a portion of the overall range of this population has been surveyed, precluding evaluation of abundance of the entire stock.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for this species in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii pelagic stock of false killer whales is calculated as the minimum population estimate for the U.S. EEZ of the Hawaiian Islands (928) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a stock of unknown status with a Hawaiian Islands EEZ mortality and serious injury rate CV <= 0.30; Wade and Angliss 1997), resulting in a PBR of 9.3 false killer whales per year.

STATUS OF STOCK

The status of the Hawaii pelagic stock of false killer whales relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Concentrations of polychlorinated biphenyls (PCBs) exceeded proposed threshold levels for health effects in 84% of sampled MHI insular false killer whales (Foltz *et al.* 2014), and elevated concentrations are also expected in pelagic false killer whales given the amplification of these contaminants through the food chain and likely similarity in false killer whale diet across the region. This stock is not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Following the NMFS Guidelines for Assessing Marine Mammal Stocks (NMFS 2005), the status of this transboundary stock of false killer whales is assessed based on the estimated abundance and estimates of mortality and serious injury within the U.S. EEZ of the Hawaiian Islands because estimates of human-caused mortality and serious injury from all U.S. and non-U.S. sources in high seas waters are not available, and because the geographic range of this stock beyond the Hawaiian Islands EEZ is poorly known. For the 5-yr period prior to the implementation of the TRP, the average rate of mortality and serious injury to pelagic stock false killer whales within the Hawaiian Islands EEZ (13.6 animals per year) exceeded the PBR (9.3 animals per year). In most cases,

the NMFS Guidelines for Assessing Marine Mammal Stocks (NMFS 2005) suggest pooling estimates of mortality and serious injury across 5 years to reduce the effects of sampling variation. If there have been significant changes in fishery operation that are expected to affect take rates, such as the 2013 implementation of the TRP, the guidelines recommend using only the years since regulations were implemented. Using only bycatch information from 2013-2015, the estimated mortality and serious injury of false killer whales within the HI EEZ (4.1) is below the PBR (9.3). Of note, in 2014 the total number of false killer whales taken in the deep-set fishery (55) is the highest recorded since 2003 and the total estimated mortality and serious injury of false killer whales (44) is the second highest since 2003. The total estimated mortality and serious injury of false killer whales in 2015 is the 2nd highest in 5 years. The proportion of non-serious injuries is lower in 2013-2015 than the aggregate of all prior years; however, similar 3-year average non-serious injury rates have been observed previously. Further, recent studies (Carretta and Moore 2014) have argued that estimates from a single year of data can be biased when take events are rare, as are takes of false killer whales in the Hawaii-based longline fisheries, and that several years of data may need to be pooled to reduce error. For these reasons, the strategic status for this stock has been evaluated relative to the most recent 5 years of estimated mortality and serious injury. The total 5-year mortality and serious injury for 2011-2015 (7.6) is less than PBR (9.3), such that this stock is not considered a "strategic stock" under the MMPA. Additional monitoring of bycatch rates for this stock will be required before assessing whether TRP measures have reduced fishery takes below PBR. The total fishery mortality and serious injury for the Hawaii pelagic stock of false killer whales cannot be considered to be insignificant and approaching zero.

NORTHWESTERN HAWAIIAN ISLANDS STOCK

POPULATION SIZE

A 2010 line transect survey that included the waters surrounding the Northwestern Hawaiian Islands produced an estimate of 617 (CV = 1.11) false killer whales attributed to the Northwestern Hawaiian Islands stock (Bradford *et al.* 2014, 2015). This is the best available abundance estimate for false killer whales within the Northwestern Hawaiian Islands. Bradford *et al.* (2014) reported that most (64%) false killer whale groups seen during the 2010 HICEAS survey were seen moving toward the vessel when detected by the visual observers. Together with an increase in sightings close to the trackline, these behavioral data suggest vessel attraction is likely occurring and may be significant. Bradford *et al.* (2014, 2015) employed a half-normal model to minimize the effect of vessel attraction, because groups originally outside of the survey strip, and therefore unavailable for observation by the visual survey team, may have moved within the survey strip and been sighted. There is some suggestion of such attractive movement within the acoustic and visual data (Bradford *et al.* 2014) though the extent of any bias created by this movement is unknown.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate for the Northwestern Hawaiian Islands stock (Bradford *et al.* 2015) or 290 false killer whales. This estimate has not been corrected for vessel attraction and may be positively-biased.

Current Population Trend

No data are available on current population trend because there is only one estimate of abundance from 2010.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for this species in the waters surrounding the Northwestern Hawaiian Islands.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Northwestern Hawaiian Islands false killer whale stock is calculated as the minimum population estimate (290) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.40 (for a stock of unknown status, with a Hawaiian Islands EEZ mortality and serious injury rate CV > 0.8; Wade and Angliss 1997), resulting in a PBR of 2.3 false killer whales per year.

STATUS OF STOCK

The status of false killer whales in Northwestern Hawaiian Islands waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Concentrations of polychlorinated biphenyls (PCBs) exceeded proposed threshold levels for health effects in 84% of sampled MHI insular false killer whales (Foltz *et al.* 2014), and elevated concentrations are also expected in NWHI false killer whales given the amplification of these contaminants through the food chain and likely similarity in false killer whale diet across the region. Biomass of some false killer whale prey species may have declined around the Northwestern Hawaiian Islands (Oleson *et al.* 2010, Boggs & Ito 1993, Reeves *et al.* 2009), though waters within the original Papahānaumokuākea Marine National Monument have been closed to commercial longlining since 1991 and to other fishing since 2006. This stock is not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor as "depleted" under the MMPA. The rate of mortality and serious injury to NWHI false killer whales, (0.6 for 2008-2012, 0 for 2013-2015, 0.4 for 2011-2015) is less than the PBR (2.3 animals per year), but is not approaching zero mortality and serious injury rate because it exceeds 10% of PBR (NMFS 2004). Only a very small portion of the recognized stock range lies outside of the newly expanded PMNM and the expanded LLEZ, such that this stock is likely not exposed to high levels of fishing effort because commercial and recreational fishing is prohibited within Monument waters and longlines are excluded from the majority of the stock range. Additional monitoring of bycatch rates for this stock will be required before assessing whether TRP measures have reduced fishery takes to below 10% of PBR.

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KILLER WHALE (*Orcinus orca*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Killer whales have been observed in all oceans and seas of the world (Leatherwood and Dahlheim 1978). Although reported from tropical and offshore waters (Heyning and Dahlheim 1988), killer whales prefer the colder waters of both hemispheres, with greatest abundances found within 800 km of major continents (Mitchell 1975). They are considered rare in Hawaiian waters. No killer whales were seen during 1993-98 aerial surveys within about 25 nmi of the main Hawaiian Islands, but one sighting was reported during subsequent surveys (Mobley et al. 2000, 2001). Baird et al. (2006) reported 21 sighting records in Hawaiian waters between 1994 and 2004. Summer/fall shipboard surveys of U.S. Exclusive Economic Zone (EEZ) Hawaiian waters resulted in two sightings in 2002 and one in 2010. (Figure 1; Barlow 2006; Bradford et al. 2017). Three strandings have been reported since 1950 (Richards 1952, NMFS PIR Marine Mammal Reponses Network database), including one since 2007. Eighteen additional sightings were reported around the main Hawaiian Islands, French Frigate Shoals, and offshore of the

Figure 1. Locations of killer whale sightings from longline observer records (crosses; NMFS/PIR, unpublished data) and sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford et al 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Dark and light gray shading indicate the original and expanded areas of Papahanaumokuakea Marine National Monument. Dotted line represents the 1,000 m isobath.

Hawaiian islands (Baird et al. 2006). Except in the northeastern Pacific where "resident", "transient", and "offshore" stocks have been described for coastal waters of Alaska, British Columbia, and Washington to California (Bigg 1982; Leatherwood et al. 1990, Bigg et al. 1990, Ford et al. 1994), little is known about stock structure of killer whales in the North Pacific. A global-scale analysis of killer whale phylogeographic structure clustered one animal sampled near Hawaii with eastern and western North Pacific transients. The other Hawaii sample within that analysis did not cluster with any known ecotype, but had divergence time between that of transient and offshore forms (Morin et al 2010).

For the Marine Mammal Protection Act (MMPA) stock assessment reports, eight killer whale stocks are recognized within the Pacific U.S. EEZ: 1) the Eastern North Pacific Alaska Resident stock - occurring from southeastern Alaska to the Aleutian Islands and Bering Sea, 2) the Eastern North Pacific Northern Resident stock - occurring from British Columbia through part of southeastern Alaska, 3) the Eastern North Pacific Southern Resident stock – occurring mainly within the inland waters of Washington State and southern British Columbia, but also in coastal waters from British Columbia through California, 4) the Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock - occurring mainly from Prince William Sound through the Aleutian Islands and Bering Sea, 5) the AT1 Transient stock - occurring in Alaska from Prince William Sound through the Kenai Fjords, 6) the West Coast Transient stock - occurring from California through southeastern Alaska, 7) the Eastern North Pacific Offshore stock - occurring from California through Alaska, and 8) the Hawaiian stock (this report). The Hawaii stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005). Stock assessment reports for the Southern Resident, Eastern North Pacific Offshore, and Hawaiian stocks can be found in the Pacific Region stock assessment reports; all other killer whale stock assessments are included in the Alaska Region stock assessments.
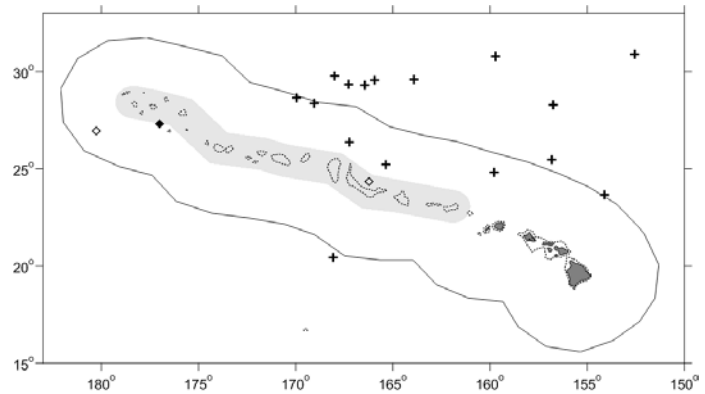
POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for killer whales, resulting in an abundance estimate of 146 (CV = 0.96) killer whales (Bradford et al. 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 349 (CV=0.98) killer whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al 1995) of the 2010 abundance estimate or 74 killer whales within the Hawaiian Islands EEZ.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current and maximum net productivity rate in Hawaiian waters.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size within the U.S. EEZ of the Hawaiian Islands (74) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a stock of unknown status with no known fishery mortality or serious injury within the Hawaiian Islands EEZ; Wade and Angliss 1997), resulting in a PBR of 0.7 killer whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. No interactions between nearshore fisheries and killer whales have been reported in Hawaiian waters. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line or gillnet fisheries because these fisheries are not observed or monitored for protected species bycatch. Killer whale interactions with Hawaii fisheries appear to be rare. In 1990, a solitary killer whale was reported to have removed the catch from a longline in Hawaii (Dollar 1991). There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no killer whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-22% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017).

STATUS OF STOCK

The Hawaii stock of killer whales is not considered strategic under the 1994 amendments to the MMPA. The status of killer whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. No habitat issues are known to be of concern for this stock. Killer whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the

MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries the total fishery mortality and serious injury can be considered to be insignificant and approaching zero.

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SHORT-FINNED PILOT WHALE (*Globicephala macrorhynchus*): Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Short-finned pilot whales are found in all oceans, primarily in tropical and warm-temperate waters. They are commonly observed around the main Hawaiian Islands and are also present around the Northwestern Hawaiian Islands (Shallenberger 1981, Baird *et al.* 2013, Bradford et al 2013). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in 25 sightings in 2002 and 36 in 2010, including a higher frequency of encounters near shore within the Northwestern Hawaiian Islands (Figure 1; Barlow 2006, Bradford *et al.* 2017). Twenty-three strandings of short-finned pilot whales have been documented from the Hawaiian Islands since 1957, including five mass strandings in May and October of 1958 and 1959 (Tomich 1986; Nitta 1991; Maldini *et al.* 2005, NMFS-PIR Marine Mammal Response Network database). There have been four strandings since 2007.

Two forms of short-finned pilot whales have been identified in Japanese waters based on pigmentation patterns and

Figure 1. Short-finned pilot whale sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford et al 2017); see Appendix 2 for details on timing and location of survey effort). Outer solid line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

differences in the shape of the heads of adult males (Kasuya *et al.* 1988). The pilot whales in Hawaiian waters are similar morphologically to the Japanese "southern form" or naisa morphotype. Recent genetic analyses confirm that short-finned pilot whales in Hawaiian waters are genetically similar to this naisa morphotype and that they may be differentiated using mtDNA markers from those animals in the eastern tropical Pacific and temperate Pacific waters (Van Cise *et al.* 2015).

Photo-identification and telemetry studies suggest there may be inshore and pelagic populations of short-finned pilot whales in Hawaiian waters. Resighting and social network analyses of individuals photographed off Hawaii Island suggest the occurrence of one large and several smaller social clusters that use those waters, with some individuals within the smaller social clusters commonly resighted off Hawaii Island (Mahaffy *et al.* 2015). Further, two groups of 14 individuals have been seen at Hawaii and elsewhere in the main Hawaiian Islands, one off Oahu and the other off Kauai. Satellite telemetry data from over 60 individuals tagged throughout the main Hawaiian Islands also support the occurrence of at least two populations (Baird 2016, Oleson et al 2013). An assessment of foraging hotspots off Hawaii Island revealed tight association between satellite-tagged short-finned pilot whales and the 1000-2500m depth range (Abecassis *et al.* 2015). More recently, Van Cise *et al.* (2017) used nuclear SNPs to assess population structure within Hawaii short-finned pilot whales and found evidence for an island-associated population in the main Hawaii Islands (MHI). Although there was some support for separation of short-finned pilot whales in the northwestern Hawaiian Islands (NWHI) from other pelagic animals, additional genetic samples may be required to test this separation further. In addition, genetic data combined with social affiliation and habitat associations suggest the MHI population is further divided into social groups, and these groups may even rise to the level of demographic-independence between those found primarily near Hawaii Island and those near Oahu and Kauai (Van Cise *et al.* 2017). Delineation of island-associated stocks in Hawaii is under review.

Fishery interactions with short-finned pilot whales demonstrate that this species also occurs in U.S. EEZ waters of Palmyra Atoll and Johnston Atoll, but it is not known whether these animals are part of the Hawaii stock or
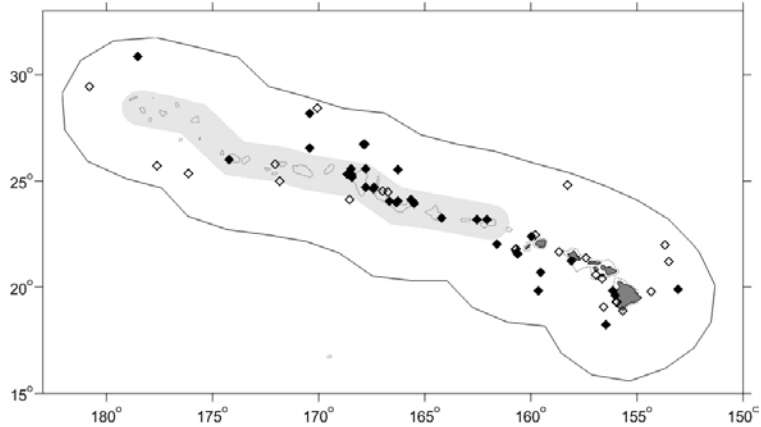
whether they represent separate stocks of short-finned pilot whales. For the Marine Mammal Protection Act (MMPA) stock assessment reports, short-finned pilot whales within the Pacific U.S. EEZ are divided into two discrete, non-contiguous areas: 1) Hawaiian waters (this report), and 2) waters off California, Oregon and Washington. The Hawaii stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. The status of the Hawaii stock is evaluated based on abundance, distribution, and human-caused impacts within the Hawaiian Islands EEZ, as such datasets are largely lacking for high seas waters (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for short-finned pilot whales, resulting in an abundance estimate of 19,503 (CV = 0.49) short-finned pilot whales (Bradford *et al.* 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 8,846 (CV=0.49) short-finned pilot whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale $g(0)$ (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific $g(0)$ values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate for the Hawaiian Islands EEZ or 13,197 short-finned pilot whales.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different $g(0)$ values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii short-finned

Figure 2. Locations of short-finned pilot whale takes (filled diamonds) and possible takes of this species (open diamonds) in Hawaii-based longline fisheries, 2011-2015. Some take locations overlap. Solid lines represent the U. S. EEZ. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

pilot whale stock is calculated as the minimum population estimate (13,197) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.40 (for a species of unknown status with a Hawaiian Islands EEZ fishery mortality and serious injury rate CV> 0.80; Wade and Angliss 1997), resulting in a PBR of 106 short-finned pilot whales per year.

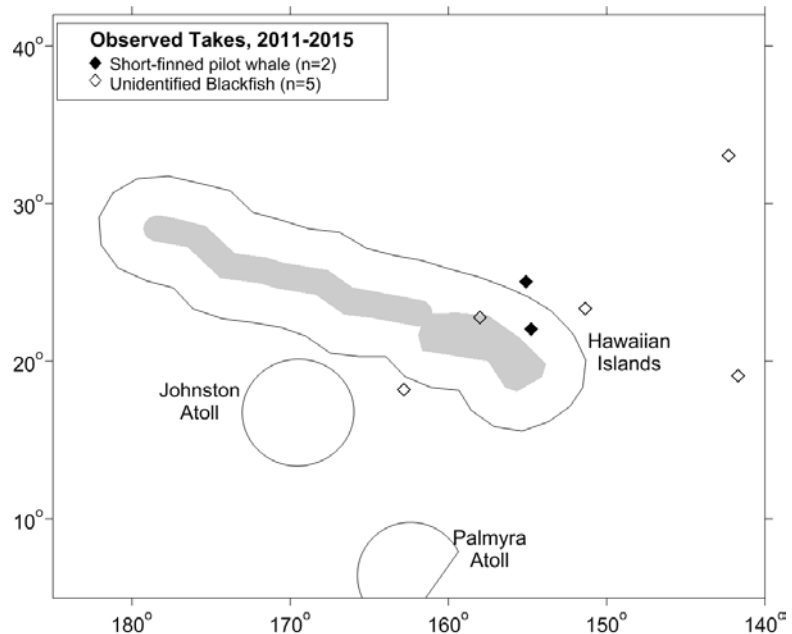## HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. Entanglement in gillnets and hooking or entanglement in various hook and line fisheries have been reported for small cetaceans in Hawaii (Nitta & Henderson, 1993). Short-finned pilot whales have been observed with fishing gear trailing from their mouths, though the specific gear types have not been identified (Baird 2016). In 2014, a short-finned pilot whale was found stranded on Oahu with large amounts of debris in its stomach, including approximately 20 lbs. of fishing line, nets, and plastic drogues (Bradford and Lyman in review). The necropsy team judged that the whale had not eaten in at least 24 hrs, but it was not clear what role the debris played in the whale's death. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line or gillnet fisheries because these fisheries are not observed or monitored for protected species bycatch.

Table 1. Summary of available information on incidental mortality and serious injury of short-finned pilot whales (Hawaii stock) and including those presumed to be short-finned pilot whales based on assignment of unidentified blackfish to this species in commercial longline fisheries, within and outside of the U.S. EEZs (McCracken 2017). Mean annual takes are based on 2011-2015 data unless otherwise indicated. Information on all observed takes (T) and combined mortality events & serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome. Unidentified blackfish are pro-rated as either false killer whales or short-finned pilot whales according to their distance from shore (McCracken 2010). CVs are estimated based on the combination of annual short-finned pilot whale and blackfish variances and do not yet incorporate additional uncertainty introduced by prorating the unidentified blackfish.

| | | | | Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of short-finned pilot whales (GM) | | | |
| | | | | Outside U.S. EEZs | | Hawaiian EEZ | |
Fishery Name	**Year**	**Data Type**	**Percent Observer Coverage**	**Obs. GM T/MSI** / **Obs. UB T/MSI**	**Estimated M&SI (CV)**	**Obs. GM T/MSI** / **Obs. UB T/MSI**	**Estimated M&SI (CV)**
Hawaii-based deep-set longline fishery	2011	Observer data	20%	0 / 1/0	1.6 (1.1)	0 / 1/1	0.1 (0.9)
	2012		20%	0 / 1/1	0.6 (0.8)	0 / 0	0 (-)
	2013		20%	1/1 / 0	4.1(0.9)	0 / 0	0 (-)
	2014		21%	0 / 0	0 (-)	0 / 0	0 (-)
	2015		21%	0 / 1/1[†]	0.7 (0.9)	1/1 / 0	4.3 (0.9)
Mean Estimated Annual Take (CV)					**1.4 (1.5)**		**0.9 (1.2)**
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	0 / 1/1	0.3	0 / 0	0
	2012		100%	0 / 0	0	0 / 0	0
	2013		100%	0 / 0	0	0 / 0	0
	2014		100%	0 / 0	0	0 / 0	0
	2015		100%	0 / 0	0	0 / 0	0
Mean Annual Takes (100% coverage)					**0.1**		**0**
Minimum total annual takes within U.S. EEZ							**0.9 (1.2)**

[†] Injury status could not be determined based on information collected by the observer. Injury status is prorated (see text).

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within

U.S. waters and on the high seas, but are prohibited from operating within the Papahanaumokuakea Marine National Monument, a region that extends 50 nmi from shore around the Northwestern Hawaiian Islands, and within the Longline Exclusion Area, a region extending 25-75 nmi from shore around the main Hawaiian Islands. Between 2011 and 2015, no short-finned pilot whales were observed hooked or entangled in the SSLL fishery (100% observer coverage), and two short-finned pilot whales were observed taken in the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017), one in high-seas waters and the other inside the Hawaiian Islands EEZ. Based on an evaluation of the observer's description of the interaction and following the most recently developed criteria for assessing serious injury in marine mammals (NMFS 2012), one short-finned pilot whales was observed dead and the other was considered seriously injured ((Bradford 2017, Bradford and Forney 2017). Five additional unidentified "blackfish" (unidentified cetaceans known to be either false killer whales or short-finned pilot whales) were taken during 2011-2015 (Bradford 2017, Bradford and Forney 2017), one within the SSLL fishery and four in the DSLL fishery. The single SSLL interaction occurred outside the Hawaiian EEZ and the animal was considered seriously injured. Of the four DSLL interactions, one occurred inside the Hawaii EEZ and was considered seriously injured, and three occurred outside the Hawaii EEZ, with one considered seriously injured, one considered not seriously injured, and one whose injury status could not be determined based on the information provided by the observer. Unidentified blackfish are prorated to each stock 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 performance and simplicity relative to a number of other more complicated models with similar output (McCracken 2010). Proration of unidentified blackfish takes introduces unquantified uncertainty into the bycatch estimates, but until all animals taken can be identified to species (e.g., photos, tissue samples), this approach ensures that potential impacts to all stocks are assessed. Average 5-yr estimates of annual mortality and serious injury for 2011-2015 are 1.5 (CV = 1.5) short-finned pilot whales outside of U.S. EEZs and 0.9 (CV = 1.2) within the Hawaiian Islands EEZ. Four additional unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which may have been short-finned pilot whales.

STATUS OF STOCK

The Hawaii stock of short-finned pilot whales is not considered strategic under the 1994 amendments to the MMPA. The status of short-finned pilot whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Short-finned pilot whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. The estimated rate of mortality and serious injury within the Hawaiian Islands EEZ (0.9 animals per year) is less than the PBR (106). Based on the available data, which indicate total fishery-related takes are less than 10% of PBR, the total fishery mortality and serious injury for short-finned pilot whales can be considered to be insignificant and approaching zero.

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BLAINVILLE'S BEAKED WHALE (*Mesoplodon densirostris*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Blainville's beaked whale has a cosmopolitan distribution in tropical and temperate waters, apparently the most extensive known distribution of any *Mesoplodon* species (Mead 1989). Forty-five sightings over 13 years were reported from the main islands by Baird *et al.* (2013), who indicated that Blainville's beaked whale represent a small proportion (2-3%) of all odontocete sightings in the main Hawaiian Islands. Shallenberger (1981) suggested that Blainville's beaked whales were present off the Waianae Coast of Oahu for prolonged periods annually. Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands, resulted in three sightings in 2002 and one in 2010; however, several sightings of unidentified *Mesoplodon* whales may have also been Blainville's beaked whale (Figure 1; Barlow 2006, Bradford *et al.* 2017).

Recent analysis of Blainville's beaked whale resightings and movements near the main Hawaiian Islands (MHI)

Figure 1. Sighting locations of *Mesoplodon densirostris* (diamonds) and unidentified *Mesoplodon* beaked whales (squares) during the 2002 (open symbols) and 2010 (black symbols) shipboard cetacean surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line indicates approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1,000m isobath.

suggest the existence of insular and offshore (pelagic) populations of this species in Hawaiian waters (McSweeney *et al.* 2007, Schorr *et al.*, 2009, Baird *et al.* 2013). Photo-identification of individual Blainville's beaked whales from Hawaii Island since 1986 reveal repeated use of this area by individuals for over 17 years (Baird *et al.* 2011) and 75% of individuals seen off Hawaii Island link by association into a single social network (Baird *et al.* 2013). Those individuals seen farthest from shore and in deep water (>2100m) have not been resighted, suggesting they may be part of an offshore, pelagic population (Baird *et al.* 2011). Twelve Blainville's beaked whales linked to the social network have been satellite tagged off Hawaii Island. All 12 individuals had movements restricted to the MHI, extending to nearshore waters of Oahu, with average distance from shore of 21.6 km (Baird *et al.* 2013, Abecassis *et al.* 2015). One individual tagged 32km from Hawaii Island did not link to the social network and had movements extending far from shore, moving over 900km from the tagging location in 20 days, approaching the edge of the Hawaiian EEZ west of Nihoa (Baird *et al.* 2011). An assessment of foraging hotspots off Hawaii Island revealed tight association between satellite-tagged Blainville's beaked whales and the 250-2500m depth contour and the occurrence of the island-associated deep mesopelagic boundary community (Abecassis *et al.* 2015). The available movement, social structure, and habitat data suggest there is likely a separate island-associated population of Blainville's beaked whales within the MHI. Formal assessment of demographic-independence has not been completed, but division of this population into a separate island-associated stock may be warranted in the future.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, three *Mesoplodon* stocks are defined within the Pacific U.S. EEZ: 1) *M. densirostris* in Hawaiian waters (this report), 2) *M. stejnegeri* in Alaskan waters, and 3) all *Mesoplodon* species off California, Oregon and Washington. The Hawaii stock of Blainville's beaked whales includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).
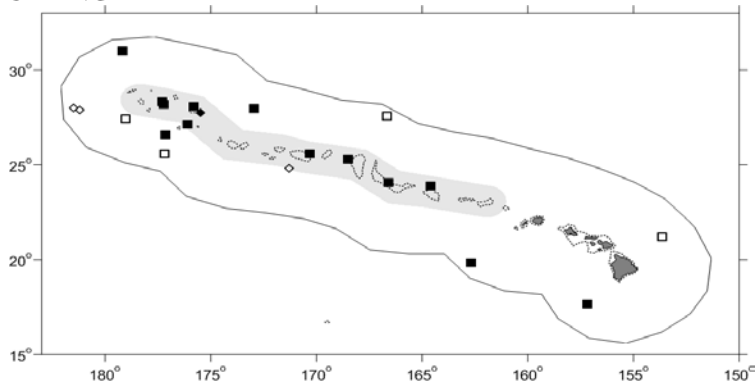
POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently reevaluated using Beaufort sea-state-specific trackline detection probabilities for beaked whales. The new g(0) values allow for use of all on-effort survey data, and resulted in an abundance estimate of 2,105 (CV = 1.13) Blainville's beaked whales (Bradford *et al.* 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same region resulted in an abundance estimate of 2,872 (CV=1.17) Blainville's beaked whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used species-specific g(0) values (Barlow 1999) (the probability of sighting and recording an animal directly on the track line) and limited the encounter data to beaufort 0-2 (Barlow 2006). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate or 980 Blainville's beaked whales within the Hawaiian Islands EEZ.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. This change in analysis methodology resulted in far less extrapolation over the survey area. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population estimate for the U.S. EEZ of the Hawaiian Islands (980) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a species of unknown status with no recent fishery mortality or serious injury within the Hawaiian Islands EEZ; Wade and Angliss 1997), resulting in a PBR of 10 Hawaii Blainville's beaked whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaii fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. No interactions between nearshore fisheries and Blainville's beaked whales have been reported in Hawaiian waters. No estimates of human-

Figure 2. Location of the Blainville's beaked whale take (cross) and the possible takes of this species (filled diamond) in Hawaii-based longline fisheries, 2011-2015. Solid lines represent the U.S. EEZ. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

caused mortality or serious injury are currently available for nearshore hook and line fisheries because these fisheries are not observed or monitored for protected species bycatch.
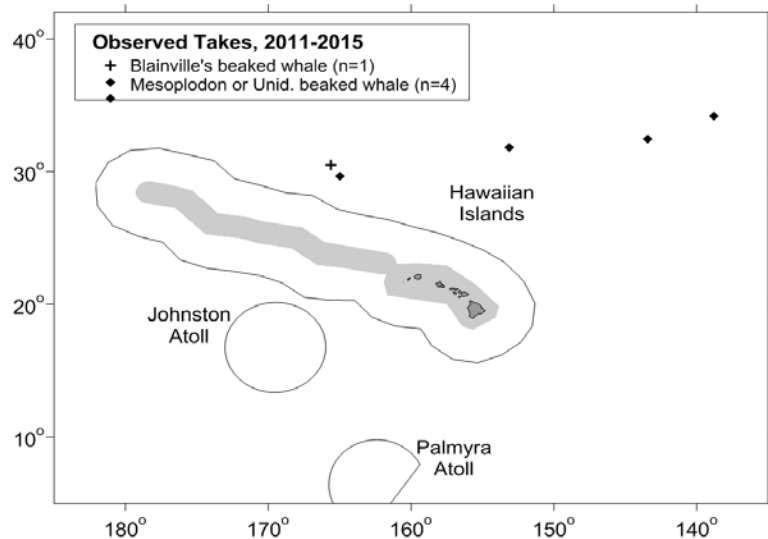
Table 1. Summary of available information on incidental mortality and serious injury of Blainville's beaked whales (Hawaii stock) in commercial longline fisheries, within and outside of the Hawaiian Islands EEZ (McCracken 2017). Mean annual takes are based on 2011-2015 data unless otherwise indicated. Information on all observed takes (T) and combined mortality events & serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome.

Fishery Name	Year	Data Type	Percent Observer Coverage	Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of Blainville's beaked whales (MD), unidentified Mesoplont whales (UM) and unidentified beaked whales (ZU)			
				Outside U.S. EEZs		Hawaiian EEZ	
				Obs. MD T/MSI Obs. UM+ZU T/MSI	Estimated MD M&SI (CV) Estimated UM+ZU MSI (CV)	Obs. MD T/MSI Obs. UM+ZU T/MSI	Estimated MD M&SI (CV) Estimated UM+ZU MSI (CV)
Hawaii-based deep-set longline fishery	2011	Observer data	20%	0	0 (-)	0	0 (-)
	2012		20%	0	0 (-)	0	0 (-)
	2013		20%	0	0 (-)	0	0 (-)
	2014		21%	0	0 (-)	0	0 (-)
	2015		21%	0	0 (-)	0	0 (-)
Mean Estimated Annual MD Take (CV)				**0 (-)**		**0 (-)**	
Mean Estimated Annual UM+ZU Take (CV)				**0 (-)**		**0 (-)**	
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	1/0 2/2	0 2	0	0
	2012		100%	0	0	0	0
	2013		100%	0 2/1	0 1	0	0
	2014		100%	0	0	0	0
	2015		100%	0	0	0	0
Mean Annual MD Takes (100% coverage)				**0**		**0**	
Mean Annual UM + ZU Takes (100% coverage)				**0.6**		**0**	
Minimum total annual MD takes within U.S. EEZ						**0 (-)**	

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no Blainville's beaked whale was observed killed or seriously injured in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-22% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017) within the Hawaiian EEZ. One Blainville's beaked whale was observed taken, but not seriously injured, on the high seas in the SSLL fishery (Bradford 2017, Bradford and Forney 2017). One unidentified *Mesoplodon* whale and two unidentified beaked whale were taken outside of the Hawaiian EEZ in the SSLL fishery and all were considered to be seriously injured. Average 5-yr estimates of annual mortality and serious injury for 2011-2015 are zero Blainville's beaked whales within or outside of the U.S. EEZs, and 0.6 (CV = 0) *Mesoplodon* or unidentified beaked whales outside the U.S. EEZs (Table 1). Four unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of

which may have been Blainville's beaked whales (Bradford 2017, Bradford and Forney 2017).

Other Mortality

Anthropogenic sound sources, such as military sonar and seismic testing have been implicated in the mass strandings of beaked whales, including atypical events involving multiple beaked whale species (Simmonds and Lopez-Jurado 1991, Frantiz 1998, Anon. 2001, Jepson *et al.* 2003, Cox *et al.* 2006). While D'Amico *et al.* (2009) note that most mass strandings of beaked whales are unassociated with documented sonar activities, lethal or sub-lethal effects of such activities would rarely be documented, due to the remote nature of such activities and the low probability that an injured or dead beaked whale would strand. Filadelpho *et al.* (2009) reported statistically significant correlations between military sonar use and mass strandings of beaked whales in the Mediterranean and Caribbean Seas, but not in Japanese and Southern California waters, and hypothesized that regions with steep bathymetry adjacent to coastlines are more conducive to stranding events in the presence of sonar use. In Hawaiian waters, Faerber & Baird (2010) suggest that the probability of stranding is lower than in some other regions due to nearshore currents carrying animals away from beaches, and that stranded animals are less likely to be detected due to low human population density near many of Hawaii's beaches. Actual and simulated sonar are known to interrupt the foraging dives and echolocation activities of tagged beaked whales (Tyack *et al.* 2011, DeRuiter *et al.* 2013). Cuvier's beaked whales tagged and tracked during simulated mid-frequency sonar exposure showed avoidance reactions, including prolonged diving, cessation of echolocation click production associated with foraging, and directional travel away from the simulated sonar source (DeRuiter *et al.* 2013). Blainville's beaked whale presence was monitored on hydrophone arrays before, during, and after sonar activities on a Caribbean military range, with evidence of avoidance behavior: whales were detected throughout the range prior to sonar exposure, not detected in the center of the range coincident with highest sonar use, and gradually returned to the range center after the cessation of sonar activity (Tyack *et al.* 2011). Fernández *et al.* (2013) report that there have been no mass strandings of beaked whales in the Canary Islands following a 2004 ban on sonar activities in that region. The absence of beaked whale bycatch in California drift gillnets following the introduction of acoustic pingers into the fishery implies additional sensitivity of beaked whales to anthropogenic sound (Carretta *et al.* 2008, Carretta and Barlow 2011). The impact of sonar exercises on resident versus offshore beaked whales may be significantly different with offshore animals less frequently exposed, and possibly subject to more extreme reactions (Baird *et al.* 2009). No estimates of potential mortality or serious injury are available for U.S. waters.

STATUS OF STOCK

The Hawaii stock of Blainville's beaked whales is not considered strategic under the 1994 amendments to the MMPA The status of Blainville's beaked whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Blainville's beaked whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Given the absence of recorded recent fishery-related mortality or serious injuries within U.S. EEZs, the total fishery mortality and serious injury can be considered to be insignificant and approaching zero. The impacts of anthropogenic sound on beaked whales remain a concern (Barlow and Gisiner 2006, Cox *et al.* 2006, Hildebrand *et al.* 2005, Weilgart 2007). One Blainville's beaked whale found stranded on the main Hawaiian Islands has tested positive for *Morbillivirus* (Jacob *et al.* 2016). The presence of *morbillivirus* in the 3 known species of beaked whales in Hawaiian waters, raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

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CUVIER'S BEAKED WHALE (*Ziphius cavirostris*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Cuvier's beaked whales occur in all oceans and major seas (Heyning 1989). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands, resulted in four sightings in 2002 and 22 in 2010, including markedly higher sighting rates during nearshore surveys in the Northwestern Hawaiian Islands. (Figure 1; Barlow 2006, Bradford *et al.* 2017).

Resighting and movement data of individual Cuvier's beaked whales suggest the existence of insular and offshore populations of this species in Hawaiian waters. A 21-yr study off Hawaii Island suggests long-term site fidelity and year round occurrence (McSweeney *et al.* 2007). Eight Cuvier's beaked whales have been tagged off Hawaii Island since 2006, with all remaining close to the island of Hawaii for the duration of tag data received (Baird *et al.* 2013). Approximately 95% of all locations were within 45 km of

Figure 1. Cuvier's beaked whale sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument.

shore and the farthest offshore an individual was documented was 67 km (Baird *et al.* 2013). The available satellite data suggest that a resident population may occur near Hawaii Island, distinct from offshore, pelagic Cuvier's beaked whales. This conclusion is further supported by the long-term site fidelity evident from photo-identification data (McSweeney *et al.* 2007). Division of this population into a separate island-associated stock may be warranted in the future.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, Cuvier's beaked whales within the Pacific U.S. EEZ are divided into three discrete, non-contiguous areas: 1) Hawaiian waters (this report), 2) Alaskan waters, and 3) waters off California, Oregon and Washington. The Hawaii stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently reevaluated using Beaufort sea-state-specific trackline detection probabilities for beaked whales. The new g(0) values allow for use of all on-effort survey data, and resulted in an abundance estimate of 723 (CV = 0.69) Cuvier's beaked whales (Bradford *et al.* 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same region resulted in an abundance estimate of 15,242 (CV=1.43) Cuvier's beaked whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used species-specific g(0) values (Barlow 1999) (the probability of sighting and recording an animal directly on the track line) and limited the encounter data to Beaufort 0-2 (Barlow 2006). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Wade and Gerrodette (1993) estimated population
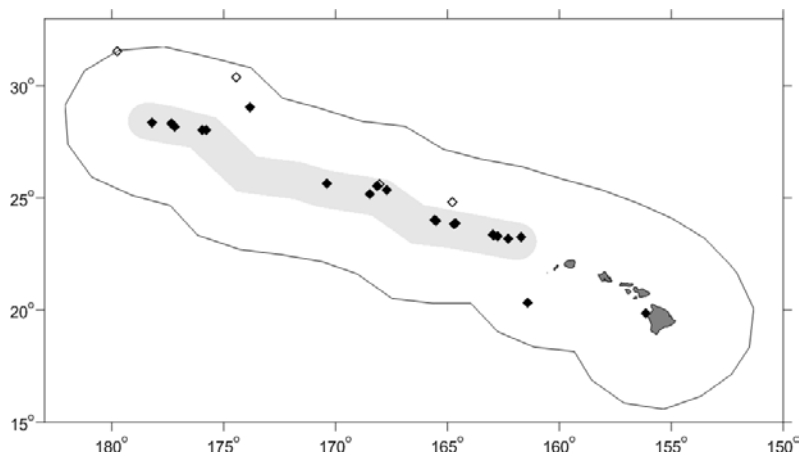
size for Cuvier's beaked whales in the eastern tropical Pacific, but it is not known whether any of these animals are part of the same population that occurs around the Hawaiian Islands.

Minimum Population Estimate

Minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate, or 428 Cuvier's beaked whales.

Current Population Trend

The significant decrease in abundance estimates between the 2002 and 2010 surveys is attributed to the use of higher sea states (beaufort 0-6) in estimating the trackline detection probability for the 2010 survey, compared to the 2002 survey, which utilized only beaufort sea state data 0 through 2 (Bradford et al 2017). This change in analysis methodology resulted in far less extrapolation over the survey area, resulting in a more representative estimate of abundance. The 2002 survey data have not been reanalyzed using this method. . Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the pelagic stock of Cuvier's beaked whales is calculated as the minimum population estimate for the U.S. EEZ of the Hawaiian Islands (428) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a species of unknown status with no known fishery mortality within the Hawaiian Islands EEZ; Wade and Angliss 1997), resulting in a PBR of 4.3 Cuvier's beaked whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. In 1998, a Cuvier's beaked whale stranded possibly entangled, with scars and cuts from fishing gear along its body (Bradford & Lyman 2013). The gear was not described. No other interactions between nearshore fisheries and Cuvier's beaked whales have been reported in Hawaiian waters. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line fisheries because these fisheries are not observed or monitored for protected species bycatch.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 02015, no Cuvier's beaked whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-22% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). Two unidentified beaked whales was taken in the SSLL fishery and considered seriously. Average 5-yr estimates of annual mortality and serious injury for 2011-2015 are zero Cuvier's beaked whales within or outside of the U.S. EEZs, and 0.4 unidentified beaked whales outside the U.S. EEZs (Table 1). Four unidentified cetaceans were taken in the DSLL fishery, and one unidentified cetacean was taken in the SSLL fishery, some of which could have been Cuvier's beaked whales (Bradford 2017, Bradford and Forney 2017).

Other Mortality

Anthropogenic sound sources, such as military sonar and seismic testing have been implicated in the mass strandings of beaked whales, including atypical events involving multiple beaked whale species (Simmonds and Lopez-Jurado 1991, Frantiz 1998, Anon. 2001, Jepson *et al.* 2003, Cox *et al.* 2006). While D'Amico *et al.* (2009) note that most mass strandings of beaked whales are unassociated with documented sonar activities, lethal or sub-lethal effects of such activities would rarely be documented, due to the remote nature of such activities and the low probability that an injured or dead beaked whale would strand. Filadelpho *et al.* (2009) reported statistically significant correlations between military sonar use and mass strandings of beaked whales in the Mediterranean and Caribbean Seas, but not in Japanese and Southern California waters, and hypothesized that regions with steep bathymetry adjacent to coastlines are more conducive to stranding events in the presence of sonar use. In Hawaiian waters, Faerber

& Baird (2010) suggest that the probability of stranding is lower than in some other regions due to nearshore currents carrying animals away from beaches, and that stranded animals are less likely to be detected due to low human population density near many of Hawaii's beaches. Actual and simulated sonar are known to interrupt the foraging dives and echolocation activities of tagged beaked whales (Tyack *et al.* 2011, DeRuiter *et al.* 2013). Cuvier's beaked whales tagged and tracked during simulated mid-frequency sonar exposure showed avoidance reactions, including prolonged diving, cessation of echolocation click production associated with foraging, and directional travel away from the simulated sonar source (DeRuiter *et al.* 2013). Blainville's beaked whale presence was monitored on hydrophone arrays before, during, and after sonar activities on a Caribbean military range, with evidence of avoidance behavior: whales were detected throughout the range prior to sonar exposure, not detected in the center of the range coincident with highest sonar use, and gradually returned to the range center after the cessation of sonar activity (Tyack *et al.* 2011). Fernández *et al.* (2013) report that there have been no mass strandings of beaked whales in the Canary Islands following a 2004 ban on sonar activities in that region. The absence of beaked whale bycatch in California drift gillnets following the introduction of acoustic pingers into the fishery implies additional sensitivity of beaked whales to anthropogenic sound (Carretta *et al.* 2008, Carretta and Barlow 2011). The impact of sonar exercises on resident versus offshore beaked whales may be significantly different with offshore animals less frequently exposed, and possibly subject to more extreme reactions (Baird *et al.* 2009). No estimates of potential mortality or serious injury are available for U.S. waters.

STATUS OF STOCK

The Hawaii stock of Cuvier's beaked whales is not considered strategic under the 1994 amendments to the MMPA. The status of Cuvier's beaked whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Cuvier's beaked whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. There have been no reported fishery related mortality or injuries within the Hawaiian Islands EEZ, such that the total mortality and serious injury can be considered to be insignificant and approaching zero. The impacts of anthropogenic sound on beaked whales remain a concern (Barlow and Gisiner 2006, Cox *et al.* 2006, Hildebrand *et al.* 2005, Weilgart 2007). One Cuvier's beaked whale found stranded on the main Hawaiian Islands tested positive for *Morbillivirus* (Jacob *et al.* 2016). The presence of *morbillivirus* in all 3 known species of beaked whales in Hawaiian waters (Jacob et al 2016), raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including the cumulative impacts of disease with other stressors.

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LONGMAN'S BEAKED WHALE (*Indopacetus pacificus*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Longman's beaked whale is considered one of the least known cetacean species (Jefferson *et al.*. 1993; Rice 1998; Dalebout *et al.* 2003). Until recently, it was known only from two skulls found in Australia and Somalia (Longman 1926; Azzaroli 1968). Recent genetic studies (Dalebout *et al.*. 2003) have revealed that sightings of 'tropical bottlenose whales' (*Hyperoodon* sp.; Pitman *et al.*. 1999) in the Indo-Pacific region were in fact Longman's beaked whales, providing the first description of the external appearance of this species. Although originally described as *Mesoplodon pacificus* (Longman 1926), it has been proposed that this species is sufficiently unique to be placed within its own genus, *Indopacetus* (Moore 1968; Dalebout *et al.*. 2003).

Figure 1. Sighting locations of Longman's beaked whale during the 2002 (open diamond) and 2010 (black diamonds) shipboard cetacean surveys of U.S. waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line indicates approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

The distribution of Longman's beaked whale, as determined from stranded specimens and sighting records of 'tropical bottlenose whales', includes tropical waters from the eastern Pacific westward through the Indian Ocean to the eastern coast of Africa. A single stranding of Longman's beaked whale has been reported in Hawaii, in 2010 near Hana, Maui (West *et al.* 2012), and there was a single sighting off Kona over 13 years of nearshore surveys off in the leeward waters of the main Hawaiian Islands (Baird *et al.* 2013). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands, resulted in one sighting in 2002 and three in 2010 (Barlow 2006, Bradford *et al.* 2017; Figure 1).

For the Marine Mammal Protection Act (MMPA) stock assessment reports, there is one Pacific stock of Longman's beaked whales, found within waters of the Hawaiian Islands EEZ. This stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for Longman's beaked whales, resulting in an abundance estimate of 7,619 (CV = 0.66) Longman's beaked whales (Bradford *et al.*. 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 1,007 (CV=1.25) Longman's beaked whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data.
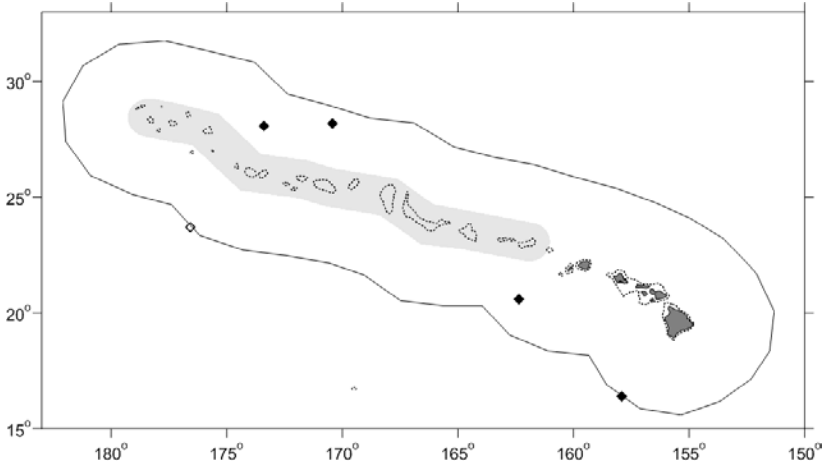
Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) around the 2010 abundance estimate, or 4,592 Longman's beaked whales within the Hawaiian Islands EEZ.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for Longman's beaked whales.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size within the U.S. EEZ of the Hawaiian Islands (4,592) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.50 (for a stock of unknown status with no known fishery mortality or serious injury within the Hawaiian Islands EEZ; Wade and Angliss 1997), resulting in a PBR of 46 Longman's beaked whales per year.

HUMAN CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality and serious injury of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. No interactions between nearshore fisheries and Longman's beaked whales have been reported in Hawaiian waters. No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line fisheries because these fisheries are not observed or monitored for protected species bycatch. There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 0215, no Longman's beaked whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-22% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). However, four unidentified cetaceans, which may have been a Longman's beaked whale, were taken in the DSLL fishery, and one unidentified cetaceans, one unidentified Mesoplodon, and two unidentified beaked whale, which may have been Longman's beaked whales were taken in the SSLL fishery.

Other Mortality

Anthropogenic sound sources, such as military sonar and seismic testing have been implicated in the mass strandings of beaked whales, including atypical events involving multiple beaked whale species (Simmonds and Lopez-Jurado 1991, Frantiz 1998, Anon. 2001, Jepson *et al.*. 2003, Cox *et al.*. 2006). While D'Amico *et al.*. (2009) note that most mass strandings of beaked whales are unassociated with documented sonar activities, lethal or sub-lethal effects of such activities would rarely be documented, due to the remote nature of such activities and the low probability that an injured or dead beaked whale would strand. Filadelpho *et al.*. (2009) reported statistically significant correlations between military sonar use and mass strandings of beaked whales in the Mediterranean and Caribbean Seas, but not in Japanese and Southern California waters, and hypothesized that regions with steep bathymetry adjacent to coastlines are more conducive to stranding events in the presence of sonar use. In Hawaiian waters, Faerber & Baird (2010) suggest that the probability of stranding is lower than in some other regions due to nearshore currents carrying animals away from beaches, and that stranded animals are less likely to be detected due to low human population density near many of Hawaii's beaches. Actual and simulated sonar are known to interrupt the foraging dives and echolocation activities of tagged beaked whales (Tyack *et al.*. 2011, DeRuiter *et al.*. 2013). Cuvier's beaked whales tagged and tracked during simulated mid-frequency sonar exposure showed avoidance reactions, including prolonged diving, cessation of echolocation click production associated with foraging, and directional travel away from the simulated sonar source (DeRuiter *et al.*. 2013). Blainville's beaked whale presence

was monitored on hydrophone arrays before, during, and after sonar activities on a Caribbean military range, with evidence of avoidance behavior: whales were detected throughout the range prior to sonar exposure, not detected in the center of the range coincident with highest sonar use, and gradually returned to the range center after the cessation of sonar activity (Tyack *et al.*. 2011). Fernández *et al.*. (2013) report that there have been no mass strandings of beaked whales in the Canary Islands following a 2004 ban on sonar activities in that region. The absence of beaked whale bycatch in California drift gillnets following the introduction of acoustic pingers into the fishery implies additional sensitivity of beaked whales to anthropogenic sound (Carretta *et al.*. 2008, Carretta and Barlow 2011). No estimates of potential mortality or serious injury are available for U.S. waters.

STATUS OF STOCK

The Hawaii stock of Longman's beaked whales is not considered strategic under the 1994 amendments to the MMPA. The status of Longman's beaked whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Longmans' beaked whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries, the total fishery mortality and serious injury can be considered to be insignificant and approaching zero. The impacts of anthropogenic sound on beaked whales remain a concern (Barlow and Gisiner 2006, Cox *et al.*. 2006, Hildebrand *et al.* 2005, Weilgart 2007). The first confirmed case of *morbillivirus* in a Hawaiian cetacean was found in a subadult Longman's beaked whale stranded on Maui in 2010 (West *et al.* 2012). The presence of *morbillivirus* in all 3 known species of beaked whales in Hawaiian waters (Jacob *et al.* 2016), raises concerns about the history and prevalence of this disease in Hawaii and the potential population impacts, including cumulative impacts of disease with other stressors.

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SPERM WHALE (*Physeter macrocephalus*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Sperm whales are widely distributed across the entire North Pacific and into the southern Bering Sea in summer but the majority are thought to be south of 40°N in winter (Rice 1974, 1989; Gosho *et al.* 1984; Miyashita *et al.* 1995). For management, the International Whaling Commission (IWC) had divided the North Pacific into two management regions (Donovan 1991) defined by a zig-zag line which starts at 150°W at the equator to 160°W between 40-50°N, and ending at 180°W north of 50°N; however, the IWC has not reviewed this stock boundary in many years (Donovan 1991). Summer/fall surveys in the eastern tropical Pacific (Wade and Gerrodette 1993) show that although sperm whales are widely distributed in the tropics, their relative abundance tapers off markedly westward towards the middle of the tropical Pacific (near the IWC stock boundary at 150°W) and tapers off northward towards the tip of Baja California. The Hawaiian Islands marked the center of a major nineteenth century whaling ground for sperm whales (Gilmore 1959; Townsend 1935). Since 1936, at least 28 strandings have been reported from the Hawaiian

Figure 1. Sperm whale sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobaths.

Islands (Woodward 1972; Nitta 1991; Maldini *et al.* 2005, NMFS PIR Marine Mammal Response Network database), including 7 since 2007. Sperm whales have also been sighted throughout the Hawaiian EEZ, including nearshore waters of the main and Northwestern Hawaiian Islands (Rice 1960; Baird 2016, Barlow 2006, Lee 1993; Mobley *et al.* 2000, Shallenberger 1981). In addition, the sounds of sperm whales have been recorded throughout the year off Oahu (Thompson and Friedl 1982). Summer/fall shipboard surveys of waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in 43 sperm whale sightings in 2002 and 46 in 2010 throughout the study area (Figure 1; Barlow 2006, Bradford *et al.* 2017).

The stock identity of sperm whales in the North Pacific has been inferred from historical catch records (Bannister and Mitchell 1980) and from trends in CPUE and tag-recapture data (Ohsumi and Masaki 1977). A 1997 survey designed specifically to investigate stock structure and abundance of sperm whales in the northeastern temperate Pacific revealed no apparent hiatus in distribution between the U.S. EEZ off California and areas farther west, out to Hawaii (Barlow and Taylor 2005). Recent genetic analyses revealed significant differences in mitochondrial and nuclear DNA and in single-nucleotide polymorphisms between sperm whales sampled off the coast of California, Oregon and Washington and those sampled near Hawaii and in the eastern tropical Pacific (ETP) (Mesnick et al 2011). These results suggest demographic independence between matrilineal groups found California, Oregon, and Washington, and those found elsewhere in the central and eastern tropical Pacific. Further, assignment tests identified male sperm whales sampled in the sub-Arctic with each of the three regions, suggesting mixing of males from potentially several populations during the summer (Mesnick *et al.* 2011).

For the Marine Mammal Protection Act (MMPA) stock assessment reports, sperm whales within the Pacific U.S. EEZ are divided into three discrete, non-contiguous stocks: 1) waters around Hawaii (this report), 2) California, Oregon and Washington waters, and 3) Alaskan waters. The Hawaii stock includes animals found both within the
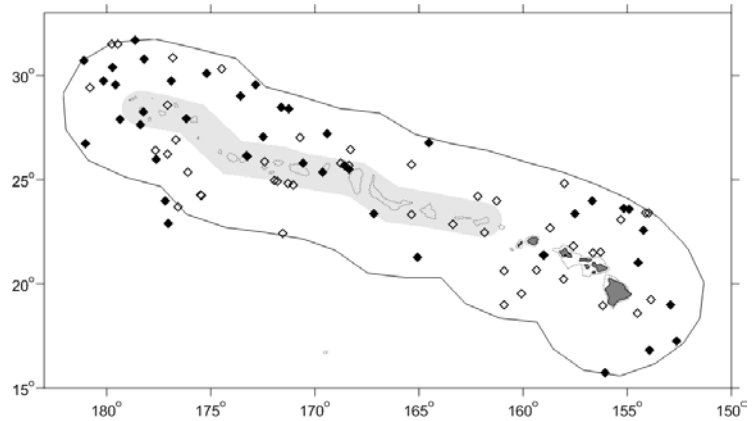
Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of the Hawaii stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for sperm whales, resulting in an abundance estimate of 4,559 (CV = 0.33) sperm whales (Bradford *et al.* 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 6,919 (CV=0.81) sperm whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. A large 1982 abundance estimate for the entire eastern North Pacific (Gosho *et al.* 1984) was based on a CPUE method which is no longer accepted as valid by the International Whaling Commission. A spring 1997 combined visual and acoustic line-transect survey conducted in the eastern temperate North Pacific resulted in estimates of 26,300 (CV=0.81) sperm whales based on visual sightings, and 32,100 (CV=0.36) based on acoustic detections and visual group size estimates (Barlow and Taylor 2005). Sperm whales appear to be a good candidate for acoustic surveys due to the increased range of detection; however, visual estimates of group size are still required (Barlow and Taylor 2005). In the eastern tropical Pacific, the abundance of sperm whales has been estimated as 22,700 (95% C.I.=14,800-34,600; Wade and Gerrodette 1993). However, it is not known whether any or all of these animals routinely enter the U.S. EEZ of the Hawaiian Islands.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) around the 2010 abundance estimate or 3,478 sperm whales within the Hawaiian Islands EEZ.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data on current or maximum net productivity rate are available.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of sperm whales is calculated as the minimum population size (3,478) within the U.S. EEZ of the Hawaiian Islands <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.2 (for an endangered species with $N_{min} > 1,500$ and $CV_{Nmin} > 0.50$, with low vulnerability to extinction; (Taylor *et al.* 2003), resulting in a PBR of 14 sperm whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. One stranded sperm whale was found with fishing line and netting its stomach, though it is unclear whether the gear caused its death, nor what fisheries the gear came from (NMFS PIR MMRN). No estimates of human-caused mortality or serious injury are currently available for nearshore hook and line fisheries because these fisheries are not observed or monitored for protected species bycatch.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas Between 2011 and 2015, no sperm whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) and one was observed either hooked or entangled in the DSLL fishery (20-

21% observer coverage) (Bradford 2017, Bradford and Forney 2017). The observer could not determine whether the whale was hooked or entangled; however, the mainline came under tension when the animal surfaced. The whale was cut free with the hook, 0.5m wire leader, 45g weight, 12m of branchline, and 25-30 ft of mainline possibly attached. This interaction was prorated as 75% probability of serious injury because the whale was hooked or entangled but the exact nature of the injury could not be determined (Bradford & Forney 2017).

This determination is based on an evaluation of the observer's description of the interaction and following the most recently developed criteria for assessing serious injury in marine mammals (NMFS 2012). The prorating of serious injury is based on the proportion of known outcomes for whales with similar fisheries interactions in other regions. Average 5-yr estimates of annual mortality and serious injury for sperm whales during 2011-2015 are zero sperm whales outside of U.S. EEZs, and 0.7 (CV = 0.9) within the Hawaiian Islands EEZ (Table 1, McCracken 2017).
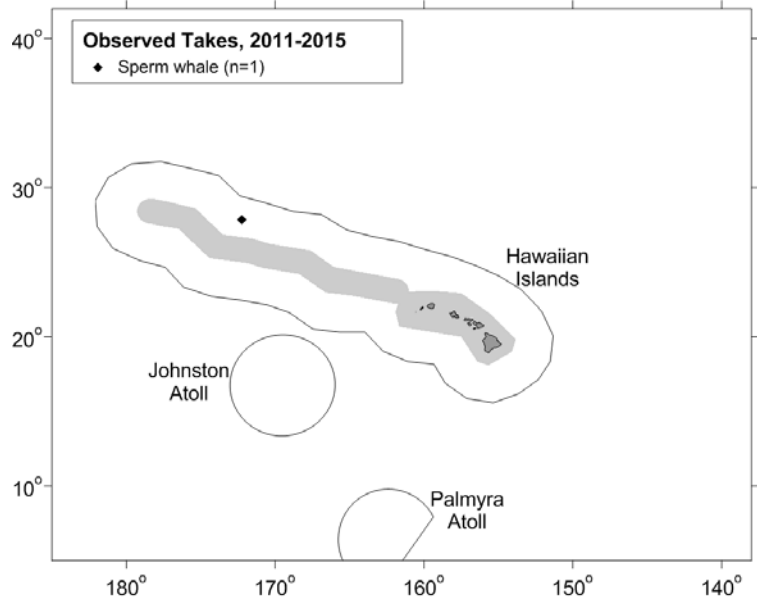
Figure 2. Locations of observed sperm whale bycatch (filled diamonds) in the Hawaii-based longline fishery, 2011-2015. Solid lines represent the U.S. EEZ. Gray shading notes areas closed to longline fishing. Fishery descriptions are provided in Appendix 1.

Table 1. Summary of available information on incidental mortality and serious injury of sperm whales in commercial longline fisheries, within and outside of the U.S. EEZs (McCracken 2017). Mean annual takes are based on 2011-2015 data. Information on all observed takes (T) and combined mortality events & serious injuries (MSI) is included. Total takes were prorated to deaths, serious injuries, and non-serious injuries based on the observed proportions of each outcome.

Fishery Name	Year	Data Type	Percent Observer Coverage	Observed total interactions (T) and mortality events, and serious injuries (MSI), and total estimated mortality and serious injury (M&SI) of sperm whales			
				Outside U.S. EEZs		Hawaiian EEZ	
				Obs. T/MSI	Estimated M&SI (CV)	Obs. T/MSI	Estimated M&SI (CV)
Hawaii-based deep-set longline fishery	2011	Observer data	20%	0	0 (-)	1/1*	3 (0.8)
	2012		20%	0	0 (-)	0	0 (-)
	2013		20%	0	0 (-)	0	0 (-)
	2014		21%	0	0 (-)	0	0 (-)
	2015		21%	0	0 (-)	0	0 (-)
Mean Estimated Annual Take (CV)					**0 (-)**		**0.7 (0.9)**
Hawaii-based shallow-set longline fishery	2011	Observer data	100%	0	0	0	0
	2012		100%	0	0	0	0
	2013		100%	0	0	0	0
	2014		100%	0	0	0	0
	2015		100%	0	0	0	0
Mean Annual Takes (100% coverage)							**0**
Minimum total annual takes within U.S. EEZ							**0.7 (0.9)**

*This injury was prorated 75% probability of being a serious injury based on known outcomes from other whales with this injury type (NOAA 2012).

Historical Mortality

Between 1800 and 1909, about 60,842 sperm whales were estimated taken in the North Pacific (Best 1976). The reported take of North Pacific sperm whales by commercial whalers between 1947 and 1987 totaled 258,000 (C. Allison, pers. comm.). Factory ships operated as far south as 20°N (Ohsumi 1980). Ohsumi (1980) lists an additional 28,198 sperm whales taken mainly in coastal whaling operations from 1910 to 1946. Based on the massive under-reporting of Soviet catches, Brownell *et al.* (1998) estimated that about 89,000 whales were additionally taken by the Soviet pelagic whaling fleet between 1949 and 1979. Japanese coastal operations apparently also under-reported catches by an unknown amount (Kasuya 1998). Thus a total of at least 436,000 sperm whales were taken between 1800 and the end of commercial whaling for this species in 1987. Of this grand total, an estimated 33,842 were taken by Soviet and Japanese pelagic whaling operations in the eastern North Pacific from the longitude of Hawaii to the U.S. West coast, between 1961 and 1976 (Allen 1980, IWC statistical Areas II and III), and 965 were reported taken in land-based U.S. West coast whaling operations between 1947 and 1971 (Ohsumi 1980). In addition, 13 sperm whales were taken by shore whaling stations in California between 1919 and 1926 (Clapham *et al.* 1997). There has been a prohibition on taking sperm whales in the North Pacific since 1988, but large-scale pelagic whaling stopped earlier, in 1980. Some of the whales taken during the whaling era were certainly from a population or populations that occur within Hawaiian waters.

STATUS OF STOCK

The only estimate of the status of North Pacific sperm whales in relation to carrying capacity (Gosho *et al.* 1984) is based on a CPUE method which is no longer accepted as valid. The status of sperm whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Sperm whales are formally listed as "endangered" under the Endangered Species Act (ESA), and consequently the Hawaiian stock is automatically considered as a "depleted" and "strategic" stock under the MMPA. The estimated rate of fisheries related mortality or serious injury within the Hawaiian Islands EEZ (0.7 animals per year) is less than the PBR (13.9). Insufficient information is available to determine whether the total fishery mortality and serious injury for sperm whales is insignificant and approaching zero mortality and serious injury rate. The increasing level of anthropogenic noise in the world's oceans has been suggested to be a habitat concern for whales (Richardson *et al.* 1995), particularly for deep-diving whales like sperm whales that feed in the oceans' "sound channel". One sperm whale stranded in the main Hawaiian Islands tested positive for both *Brucella* and *Morbillivirus* (Jacob *et al.* 2016). *Brucella* is a bacterial infection that if common in the population may limit recruitment by compromising male and female reproductive systems, and can also cause neurological disorders that may result in death (Van Bressem *et al.* 2009). *Morbillivus* is known to trigger lethal disease in cetaceans (Van Bressem *et al.* 2009); however, investigation of the pathology of the stranded sperm whale suggests that *Brucella* was more likely the cause of death in this sperm whale. The presence of *Morbillivirus* in 10 species (Jacob *et al.* 2016) and *Brucella* in 3 species (Cherbov 2010) raises concerns about the history and prevalence of these diseases in Hawaii and the potential population impacts on Hawaiian cetaceans. It is not known if *Brucella or Morbillivirus* are common in the Hawaii stock.

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BLUE WHALE (*Balaenoptera musculus musculus*):
Central North Pacific Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

The International Whaling Commission (IWC) has formally considered only one management stock for blue whales in the North Pacific (Donovan 1991), but up to five populations have been proposed (Reeves et al. 1998). Rice (1974) hypothesized that blue whales from Baja California migrated far offshore to feed in the eastern Aleutians or Gulf of Alaska and returned to feed in California waters; though more recently concluded that the California population is separate from the Gulf of Alaska population (Rice 1992). Length frequency analyses (Gilpatrick et al. 1996) and photo-identification studies (Calambokidis et al. 1995) through the 1990s supported separate populations for blue whales feeding off California and those feeding in Alaskan waters. Whaling catch data indicated that whales feeding along the Aleutian Islands were probably part of a central Pacific stock (Reeves et al. 1998), which was thought to migrate to offshore waters north of Hawaii in winter (Berzin and Rovnin 1966). Blue whale feeding aggregations have not been found in Alaska despite several surveys (Leatherwood et al. 1982; Stewart et al. 1987; Forney and Brownell 1996).

Figure 1. Locations of blue whale sightings made by observers aboard Hawaii-based longline fishing vessels between July 1994 and December 2009 (crosses, NMFS/PIR unpublished data), and location of a single blue whale sighting during a 2010 (black diamond) shipboard cetacean survey of U.S. EEZ waters surrounding the Hawaiian Islands (Bradford et al. 2017; see Appendix 2 for details on timing and location of survey effort). Outer line indicates approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

More recently, analyses of acoustic data obtained throughout the North Pacific (Stafford et al. 2001; Stafford 2003) have revealed two distinct blue whale call types, suggesting two North Pacific stocks: eastern and central (formerly western). The regional occurrence patterns suggest that blue whales from the eastern North Pacific stock winter off Mexico, Central America, and as far south as $8°$ S (Stafford et al. 1999), and feed during summer off the U. S. West Coast and to a lesser extent in the Gulf of Alaska. This stock has previously been observed to feed in waters off California (and occasionally as far north as British Columbia; Calambokidis et al. 1998) in summer/fall (from June to November) migrating south to productive areas off Mexico (Calambokidis et al. 1990) and as far south as the Costa Rica Dome (10° N) in winter/spring (Mate et al. 1999, Stafford et al. 1999). Blue whales belonging to the central Pacific stock appear to feed in summer southwest of Kamchatka, south of the Aleutians, and in the Gulf of Alaska (Stafford 2003; Watkins et al. 2000), and in winter migrate to lower latitudes in the western and central Pacific, including Hawaii (Stafford et al. 2001).

The first published sighting record of blue whales near Hawaii is that of Berzin and Rovnin (1966), though recently, two blue whales were seen with fin whales and an unidentified rorqual in November 2010 during a survey of Hawaiian U.S. EEZ waters (Bradford et al. 2017). Four sightings have been made by observers on Hawaii-based longline vessels (Figure 1; NMFS/PIR, unpublished data). Additional evidence that blue whales occur in this area comes from acoustic recordings made off Oahu and Midway Islands (Northrop et al. 1971; Thompson and Friedl 1982), which likely included at least some whales within the EEZ. The recordings made off Hawaii showed bimodal peaks throughout the year (Stafford et al. 2001), with central Pacific call types heard during winter and eastern Pacific calls heard during summer. For the Marine Mammal Protection Act (MMPA) stock assessment reports, there are two blue whale stocks within the Pacific U.S. EEZ: 1) the central North Pacific stock (this report), which includes whales
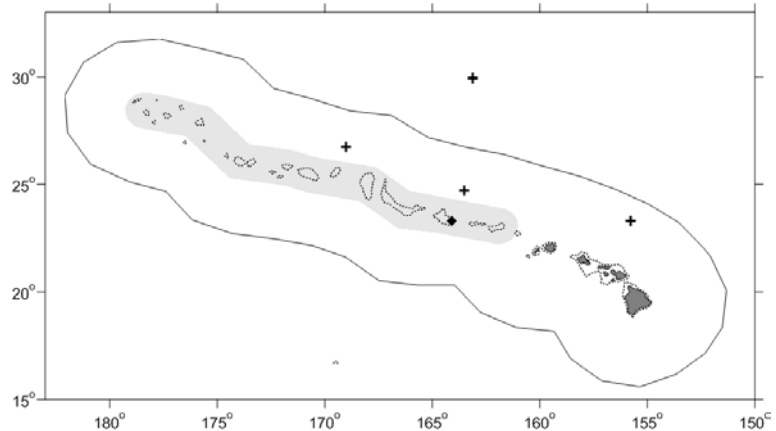
found around the Hawaiian Islands during winter and 2) the eastern North Pacific stock, which feeds primarily off California.

POPULATION SIZE
A 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ resulted in a summer/fall abundance estimate of 133 (CV = 1.09) blue whales (Bradford et al. 2017). This is currently the best available abundance estimate for this stock within the Hawaii EEZ, but the majority of blue whales would be expected to be at higher latitudes feeding grounds at this time of year. Wade and Gerrodette (1993) estimated 1,400 blue whales for the eastern tropical Pacific from summer-fall line-transect surveys in the 1980s, though it is unclear how much overlap there is between blue whales there and those found near Hawaii. No blue whale sightings were made during summer/fall 2002 shipboard surveys of the entire Hawaiian Islands EEZ (Barlow 2006).

Minimum Population Estimate
The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al. 1995) of the 2010 abundance estimate, or 63 blue whales within the Hawaiian Islands EEZ.

Current Population Trend
The first sightings of blue whales during systematic surveys occurred in 2010, and there is currently insufficient data to assess population trends.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES
No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information
There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no blue whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-22% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017).

Historical Mortality
At least 9,500 blue whales were taken by commercial whalers throughout the North Pacific between 1910 and 1965 (Ohsumi and Wada 1972). Some proportion of this total may have been from a population or populations that migrate seasonally into the Hawaiian EEZ. The species has been protected in the North Pacific by the IWC since 1966.

STATUS OF STOCK
The status of blue whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Blue whales are formally listed as "endangered" under the Endangered Species Act (ESA), and consequently the central Pacific stock is automatically considered as a "depleted" and "strategic" stock under the MMPA. Because there have been no reported fishery related mortality or serious injuries of blue whales within the Hawaiian Islands EEZ, the total fishery-related mortality and serious injury of this stock can be considered to be insignificant and approaching zero. Increasing levels of anthropogenic noise in the world's oceans has been suggested to be a habitat concern for blue whales (Reeves et al. 1998). Tagged blue whales exposed to simulated mid-frequency sonar and pseudo-random noise demonstrated a variety of behavioral responses, including no change in behavior, termination of deep dives, directed travel away from sound sources, and cessation of feeding (Goldbogen et al. 2013). Behavioral responses were highly dependent upon the type of sound source and the behavioral state of the animal at the time of exposure (Friedlaender et al. 2016), with more clear and significant response from deep-feeding whales than those in other behavioral states.. The authors stated that behavioral responses to such sounds are influenced by a complex interaction of behavioral state, environmental context, and prior exposure of individuals to such sound sources. One concern expressed by the authors is if blue whales did not habituate to such sounds near

feeding areas that "repeated exposures could negatively impact individual feeding performance, body condition and ultimately fitness and potentially population health." Currently, no evidence indicates that such reduced population health exists, but such evidence would be difficult to differentiate from natural sources of reduced fitness or mortality in the population.

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FIN WHALE (*Balaenoptera physalus physalus*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Fin whales are found throughout all oceans and seas of the world from tropical to polar latitudes. They have been considered rare in Hawaiian waters and are absent to rare in eastern tropical Pacific waters (Hamilton *et al.* 2009). Balcomb (1987) observed 8-12 fin whales in a multispecies feeding assemblage on 20 May 1966 approx. 250 mi. south of Honolulu. Additional sightings were reported north of Oahu in May 1976, in the Kauai Channel in February 1979 (Shallenberger 1981), north of Kauai in February 1994 (Mobley *et al.* 1996), and off Lanai in 2012 (Baird 2016). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in five sightings in 2002 and two sightings in 2010 (Barlow 2003, Bradford et al 2017; Figure 1). A single stranding was reported on Maui in 1954 (Shallenberger 1981). Thompson and Friedl (1982; and see Northrop *et al.* 1968) suggested that fin whales migrate into Hawaiian waters mainly in fall and

Figure 1. Locations of fin whale sightings from longline observer records (crosses; NMFS/PIR, unpublished data) and sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2003, Bradford et al 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

winter, based on acoustic recordings off Oahu and Midway Islands. Although the exact positions of the whales producing the sounds could not be determined, at least some of them were almost certainly within the U.S. EEZ. More recently, McDonald and Fox (1999) reported an average of 0.027 calling fin whales per 1000^2 km (grouped by 8-hr periods) based on passive acoustic recordings within about 16 km of the north shore of Oahu.

The International Whaling Commission (IWC) recognized two stocks of fin whales in the North Pacific: the East China Sea and the rest of the North Pacific (Donovan 1991). Mizroch *et al.* (1984) cite evidence for additional fin whale subpopulations in the North Pacific. There is still insufficient information to accurately determine population structure, but from a conservation perspective it may be risky to assume panmixia in the entire North Pacific. In the North Atlantic, fin whales were locally depleted in some feeding areas by commercial whaling (Mizroch *et al.* 1984), in part because subpopulations were not recognized. The Marine Mammal Protection Act (MMPA) stock assessment reports recognize three stocks of fin whales in the North Pacific: 1) the Hawaii stock (this report), 2) the California/Oregon/Washington stock, and 3) the Alaska stock. The Hawaiian stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for fin whales, resulting in an abundance estimate of 154 (CV=1.05) fin whales (Bradford *et al.* 2017) in the Hawaii stock. This is currently the best available abundance estimate for this stock within the Hawaii EEZ, but the majority of fin whales would be expected to be at higher latitudes feeding grounds at this time of year. A 2002 shipboard line-transect survey of the same area resulted in an abundance estimate of 174 (CV=0.72) fin whales (Barlow 2003). Species abundances estimated from the 2002
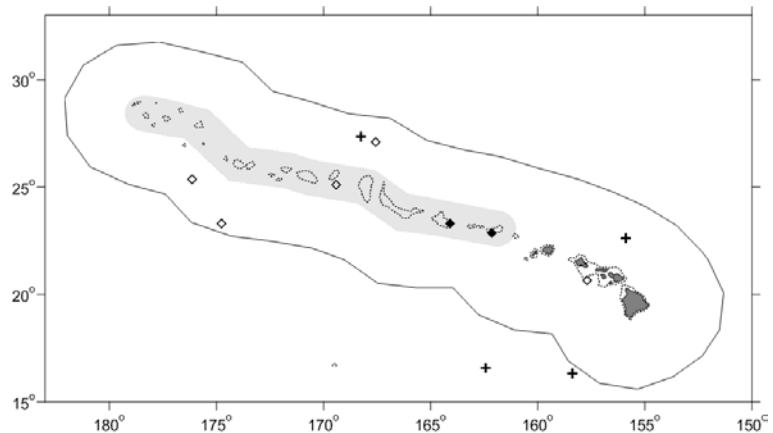
HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Using passive acoustic detections from a hydrophone north of Oahu, MacDonald and Fox (1999) estimated an average density of 0.027 calling fin whales per 1000 km^2 within about 16 km from shore. However, the relationship between the number of whales present and the number of calls detected is not known, and therefore this acoustic method does not provide an estimate of absolute abundance for fin whales.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow et al 1995) around the 2010 abundance estimate or 75 fin whales within the Hawaiian Islands EEZ.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of fin whales is calculated as the minimum population size within the U.S EEZ of the Hawaiian Islands (75) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.1 (the default value for an endangered species with Nmin <1500; Taylor et al 2003), resulting in a PBR of 0.1 fin whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, one fin whales was observed entangled in the SSLL fishery (100% observer coverage), and none were observed in the DSLL fishery (20-22% observer coverage) (Bradford 2017, McCracken 2017). The SSLL entanglement occurred outside of the Hawaiian Islands EEZ and the whale was judged to be not seriously injured (Bradford 2017). The 5-yr annual mortality and serious injury estimate for fin whales is 0 both inside and outside the Hawaiian Islands EEZ (McCracken 2017).

Historical Mortality

Large numbers of fin whales were taken by commercial whalers throughout the North Pacific from the early 20th century until the 1970s (Tønnessen and Johnsen 1982). Approximately 46,000 fin whales were taken from the North Pacific by commercial whalers between 1947 and 1987 (C. Allison, IWC, pers. comm.). Some of the whales taken may have been from a population or populations that migrate seasonally into the Hawaiian EEZ. The species has been protected in the North Pacific by the IWC since 1976.

STATUS OF STOCK

The status of fin whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Fin whales are formally listed as "endangered" under the Endangered Species Act (ESA), and consequently the Hawaiian stock is automatically considered as a "depleted" and "strategic" stock under the MMPA. Because there have been no reported fishery related mortality or serious injuries within the Hawaiian Islands EEZ, the total fishery-related mortality and serious injury of this stock can be considered to be insignificant and approaching zero. Increasing levels of anthropogenic sound in the world's oceans has been suggested to be a habitat concern for whales, particularly for baleen whales that may communicate using low-frequency sound (Croll *et al.* 2002). Behavioral changes associated with exposure to simulated mid-frequency sonar, including no change in

behavior, cessation of feeding, increased swimming speeds, and movement away from simulated sound sources has been documented in tagged blue whales (Goldbogen *et al.* 2013), but it is unknown if fin whales respond in the same manner to such sounds.

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BRYDE'S WHALE (*Balaenoptera edeni*):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Bryde's whales occur in tropical and warm temperate waters throughout the world. Leatherwood *et al.* (1982) described the species as relatively abundant in summer and fall on the Mellish and Miluoki banks northeast of Hawaii and around Midway Islands. Ohsumi and Masaki (1975) reported the tagging of "many" Bryde's whales between the Bonin and Hawaiian Islands in the winters of 1971 and 1972 (Ohsumi 1977). Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in 13 Bryde's whale sightings throughout the study area in 2002 and 30 in 2010 (Figure 1; Barlow 2006; Bradford *et al.* 2017). There is currently no biological basis for defining separate stocks of Bryde's whales in the central North Pacific. Bryde's whales were seen occasionally off southern California (Morejohn and Rice 1973) in the 1960s, but their seasonal occurrence has increased since at least 2000 based on detection of their distinctive calls (Kerosky *et al.* 2012).

Figure 1. Bryde's whale sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2006, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line represents approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

For the MMPA stock assessment reports, Bryde's whales within the Pacific U.S. EEZ are divided into two areas: 1) Hawaiian waters (this report), and 2) the eastern Pacific (east of 150°W and including the Gulf of California and waters off California). The Hawaiian stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently reevaluated using Beaufort sea-state-specific trackline detection probabilities for Bryde's whales, resulting in an abundance estimate of 1,751 (CV = 0.29) Bryde's whales (Bradford *et al.* 2017) in the Hawaii stock. A 2002 shipboard line-transect survey of the same region resulted in an abundance estimate of 469 (CV=0.45) Bryde's whales (Barlow 2006). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Tillman (1978) concluded from Japanese and Soviet CPUE data that the stock size in the North Pacific pelagic whaling grounds, mostly to the west of the Hawaiian Islands, declined from approximately 22,500 in 1971 to 17,800 in 1977. An estimate of 13,000 (CV=0.202) Bryde's whales was made from vessel surveys in the eastern tropical Pacific between 1986 and 1990 (Wade and Gerrodette 1993). The area to which this estimate applies is mainly east and somewhat south of the Hawaiian Islands, and it is not known whether these animals are part of the same population that occurs around the Hawaiian Islands.
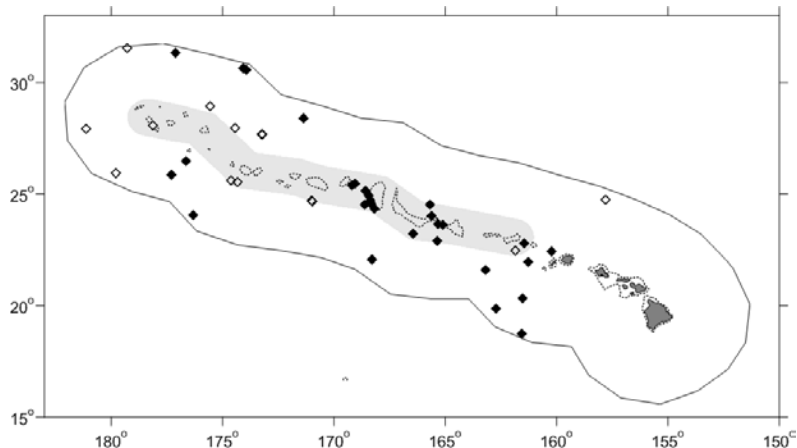
Minimum Population Estimate

Minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate, or 1,378 Bryde's whales.

Current Population Trend

Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the Hawaii stock of Bryde's whales is calculated as the minimum population size within the U.S EEZ of the Hawaiian Islands (1,378) times one half the default maximum net growth rate for cetaceans (½ of 4%) times a recovery factor of 0.50 (for a stock of unknown status with no known fishery mortality or serious injury within the Hawaiian Islands EEZ; Wade and Angliss 1997), resulting in a PBR of 14 Bryde's whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no Bryde's whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-22% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017). Large whales have been observed entangled in longline gear off the Hawaiian Islands in the past (Forney 2010).

Historical Mortality

Small numbers of Bryde's whales were taken near the Northwestern Hawaiian Islands by Japanese and Soviet whaling fleets in the early 1970s (Ohsumi 1977). Pelagic whaling for Bryde's whales in the North Pacific ended after the 1979 season (IWC 1981), and coastal whaling for this species ended in the western Pacific in 1987 (IWC 1989).

STATUS OF STOCK

The Hawaii stock of Bryde's whales is not considered strategic under the 1994 amendments to the MMPA. The status of Bryde's whales in Hawaiian waters relative to OSP is unknown, and there are insufficient data to evaluate trends in abundance. Bryde's whales are not listed as "threatened" or "endangered" under the Endangered Species Act (1973), nor designated as "depleted" under the MMPA. Given the absence of recent recorded fishery-related mortality or serious injuries within the Hawaiian Islands EEZ, the total fishery mortality and serious injury can be considered to be insignificant and approaching zero. The increasing level of anthropogenic noise in the world's oceans has been suggested to be a habitat concern for whales (Richardson *et al.* 1995, Weilgart 2007).

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SEI WHALE (Balaenoptera borealis borealis):
Hawaii Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

The International Whaling Commission (IWC) only considers one stock of sei whales in the North Pacific (Donovan 1991), but some evidence exists for multiple populations (Masaki 1977; Mizroch *et al.* 1984; Horwood 1987). Sei whales are distributed far out to sea in temperate regions of the world and do not appear to be associated with coastal features. Whaling effort for this species was distributed continuously across the North Pacific between 45-55°N (Masaki 1977). Two sei whales that were tagged off California were later killed in whaling operations off Washington and British Columbia (Rice 1974) and the movement of tagged animals has been noted in many other regions of the North Pacific. There is still insufficient information to accurately determine population structure, but from a conservation perspective it may be risky to assume panmixia in the entire North Pacific. Summer/fall shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands resulted in four sightings in 2002 and three in 2010 (Figure 1; Barlow 2003; Bradford et al 2017).
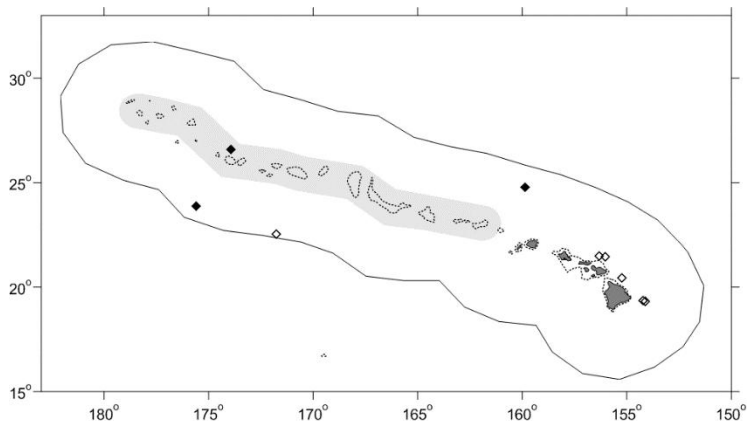
Figure 1. Sei whale sighting locations during the 2002 (open diamonds) and 2010 (black diamonds) shipboard cetacean surveys of U.S. EEZ waters surrounding the Hawaiian Islands (Barlow 2003, Bradford *et al.* 2017; see Appendix 2 for details on timing and location of survey effort). Outer line indicates approximate boundary of survey area and U.S. EEZ. Gray shading indicates area of Papahanaumokuakea Marine National Monument. Dotted line represents the 1000 m isobath.

For the Marine Mammal Protection Act (MMPA) stock assessment reports, sei whales within the Pacific U.S. EEZ are divided into three discrete, non-contiguous areas: 1) waters around Hawaii (this report), 2) California, Oregon and Washington waters, and 3) Alaskan waters. The Hawaiian stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters; however, because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of this stock is evaluated based on data from U.S. EEZ waters of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from a 2010 shipboard line-transect survey of the entire Hawaiian Islands EEZ was recently evaluated using Beaufort sea-state-specific trackline detection probabilities for sei whales, resulting in an abundance estimate of 391 (CV = 0.9) sei whales (Bradford *et al.* 2017) in the Hawaii stock. This is currently the best available abundance estimate for this stock, but the majority of sei whales would be expected to be in higher-latitude feeding grounds at this time of year. A 2002 shipboard line-transect survey of the same area resulted in a summer/fall abundance estimate of 77 (CV=1.06) sei whales (Barlow 2003). Species abundances estimated from the 2002 HICEAS survey used pooled small dolphin, large dolphin, and large whale g(0) (the probability of sighting and recording an animal directly on the track line) estimates stratified by group size (Barlow 1995). Since then, Barlow (2015) developed a more robust method for estimating species-specific g(0) values that are adjusted for the Beaufort sea states that are encountered during a survey. This new method was used for analyzing the data from the 2010 survey, but has not yet been used to analyze the 2002 data. Ohsumi and Wada (1974) estimate the pre-whaling abundance of sei whales to be 58,000-62,000 in the North Pacific. Later, Tillman (1977) used a variety of different methods to estimate the abundance of sei whales in the North Pacific and revised this pre-whaling estimate to 42,000. His estimates for the year 1974, following 27 years of whaling, ranged from 7,260 to 12,620. All methods depend on using

the history of catches and trends in CPUE or sighting rates; there have been no direct estimates of sei whale abundance in the entire North Pacific based on sighting surveys.

Minimum Population Estimate

The minimum population size is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2010 abundance estimate or 204sei whales within the Hawaiian Islands EEZ.

Current Population Trend

No data are available on current population trend. Although the population in the North Pacific is expected to have grown since being given protected status in 1976, the possible effects of continued unauthorized takes (Yablokov 1994) make this uncertain. Abundance analyses of the 2002 and 2010 datasets used different g(0) values. The 2002 survey data have not been reanalyzed using this method. This change precludes evaluation of population trends at this time. Assessment of population trend will likely require additional survey data and reanalysis of all datasets using comparable methods.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

No data are available on current or maximum net productivity rate for sei whales.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size within the U.S. EEZ of the Hawaiian Islands (204) <u>times</u> one half the default maximum net growth rate for cetaceans (½ of 4%) <u>times</u> a recovery factor of 0.1 (the default value for an endangered species with Nmin <1500; Taylor et al 2003), resulting in a PBR of 0.4 sei whales per year.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fishery Information

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the gear types used in Hawaiian fisheries are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. In March 2011 a subadult sei whale was found near Lahaina, Maui entangled with one or two wraps of heavy-gauge polypropylene line around the tailstock and trailing about 30 feet of line including a large bundle (Bradford & Lyman 2015). Closer examination also revealed line scars on the body near the dorsal fin. Although disentanglement was attempted, the gear could not be removed. Although the source of the line entangling the whale could not be determined, this injury is considered serious based on extent of trailing gear and condition of the whale (Bradford & Lyman 2015, NMFS 2012). This serious injury record results in a 5-yr average annual serious injury and mortality rate of 0.2 sei whales for the period 2011 to 2015.

There are currently two distinct longline fisheries based in Hawaii: a deep-set longline (DSLL) fishery that targets primarily tunas, and a shallow-set longline fishery (SSLL) that targets swordfish. Both fisheries operate within U.S. waters and on the high seas. Between 2011 and 2015, no sei whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (20-21% observer coverage) (Bradford 2017, Bradford and Forney 2017, McCracken 2017).

Historical Whaling

The reported take of North Pacific sei whales by commercial whalers totaled 61,500 between 1947 and 1987 (C. Allison, IWC, pers. comm.). There has been an IWC prohibition on taking sei whales since 1976, and commercial whaling in the U.S. has been prohibited since 1972.

STATUS OF STOCK

Previously, sei whales were estimated to have been reduced to 20% (8,600 out of 42,000) of their pre-whaling abundance in the North Pacific (Tillman 1977). Sei whales are formally listed as "endangered" under the Endangered Species Act (ESA), and consequently the Hawaiian stock is automatically considered as a "depleted" and "strategic" stock under the MMPA. The observed rate of fisheries related mortality or serious injury within the Hawaiian Islands EEZ (0.2 animals per year) is less than the PBR (0.4). The increasing level of anthropogenic noise in the world's oceans has been suggested to be a habitat concern for whales (Richardson *et al.* 1995 Behavioral changes associated

with exposure to simulated mid-frequency sonar, including no change in behavior, cessation of feeding, increased swimming speeds, and movement away from simulated sound sources has been documented in tagged blue whales (Goldbogen *et al.* 2013), but it is unknown if sei whales respond in the same manner to such sounds.

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Appendix 3. Pacific reports revised in 2017 are highlighted. S=strategic stock, N=non-strategic stock. unk=unknown, undet=undetermined, n/a=not applicable.

Species (Stock Area)	N est	CV N est	N min	R max	Fr	PBR	Total Annual Mortality + Serious Injury	Annual Fishery Mortality + Serious Injury	Strategic Status	Recent Abundance Surveys			SAR Last Revised
California sea lion (U.S.)	296,750	n/a	153,337	0.12	1	9,200	389	331	N	2007	2008	2011	2014
Harbor seal (California)	30,968	n/a	27,348	0.12	1	1,641	43	30	N	2004	2009	2012	2014
Harbor seal (Oregon/Washington Coast)	unk	unk	unk	0.12	1	undet	10.6	7.4	N	1999			2013
Harbor seal (Washington Northern Inland Waters)	unk	unk	unk	0.12	1	undet	9.8	2.8	N	1999			2013
Harbor seal (Southern Puget Sound)	unk	unk	unk	0.12	1	undet	3.4	1	N	1999			2013
Harbor seal (Hood Canal)	unk	unk	unk	0.12	1	undet	0.2	0.2	N	1999			2013
Northern Elephant Seal (California Breeding)	179,000	n/a	81,368	0.12	1	4,882	8.8	4	N	2002	2005	2010	2014
Guadalupe Fur Seal (Mexico to California)	20,000	n/a	15,830	0.137	0.5	542	≥3.2	≥3.2	S	2008	2009	2010	2016
Northern Fur Seal (California)	14,050	n/a	7,524	0.12	1	451	1.8	≥0.8	N	2010	2011	2013	2015
Monk Seal (Hawaii)	1,324	0.03	1,261	0.07	0.1	4.4	≥1.6	≥3.4	S	2013	2014	2015	2017
Harbor porpoise (Morro Bay)	2,917	0.41	2,102	0.04	0.5	21	≥0.6	≥0.6	N	2002	2007	2012	2013
Harbor porpoise (Monterey Bay)	3,715	0.51	2,480	0.04	0.5	25	0	0	N	2002	2007	2011	2013
Harbor porpoise (San Francisco - Russian River)	9,886	0.51	6,625	0.04	0.5	66	0	0	N	2002	2007	2011	2013
Harbor porpoise (Northern CA/Southern OR)	35,769	0.52	23,749	0.04	1	475	≥0.6	≥0.6	N	2002	2007	2011	2013
Harbor porpoise (Northern OR/Washington Coast)	21,487	0.44	15,123	0.04	0.5	151	≥3.0	≥3.0	N	2002	2010	2011	2013
Harbor porpoise (Washington Inland Waters)	11,233	0.37	8,308	0.04	0.4	66	≥7.2	≥7.2	N	2013	2014	2015	2016
Dall's porpoise (California/Oregon/Washington)	25,750	0.45	17,954	0.04	0.48	172	0.3	0.3	N	2005	2008	2014	2016
Pacific white-sided dolphin (California/Oregon/Washington)	26,814	0.28	21,195	0.04	0.45	191	7.5	1.1	N	2005	2008	2014	2016
Risso's dolphin (California/Oregon/Washington)	6,336	0.32	4,817	0.04	0.48	46	≥3.7	≥3.7	N	2005	2008	2014	2016
Common Bottlenose dolphin (California Coastal)	453	0.06	346	0.04	0.48	2.7	≥2.0	≥1.6	N	2009	2010	2011	2016
Common Bottlenose dolphin (California/Oregon/Washington Offshore)	1,924	0.54	1,255	0.04	0.45	11	≥1.6	≥1.6	N	2005	2008	2014	2016
Striped dolphin (California/Oregon/Washington)	29,211	0.20	24,782	0.04	0.48	238	≥0.8	≥0.8	N	2005	2008	2014	2016
Common dolphin, short-beaked (California/Oregon/Washington)	969,861	0.17	839,325	0.04	0.5	8,393	≥40	≥40	N	2005	2008	2014	2016
Common dolphin, long-beaked (California)	101,305	0.49	68,432	0.04	0.48	657	≥35.4	≥32.0	N	2005	2008	2014	2016
Northern right whale dolphin (California/Oregon/Washington)	26,556	0.44	18,608	0.04	0.48	179	3.8	3.8	N	2005	2008	2014	2016
Killer whale (Eastern N Pacific Offshore)	240	0.49	162	0.04	0.5	1.6	0	0	N	2005	2008	2014	2016
Killer whale (Eastern N Pacific Southern Resident)	83	n/a	83	0.035	0.1	0.14	0	0	S	2014	2015	2016	2017
Short-finned pilot whale (California/Oregon/Washington)	836	0.79	466	0.04	0.48	4.5	1.2	1.2	N	2005	2008	2014	2016
Baird's beaked whale (California/Oregon/Washington)	2,697	0.6	1,633	0.04	0.5	16.0	0	0	N	2005	2008	2014	2017
Mesoplodont beaked whales (California/Oregon/Washington)	3,044	0.54	1,967	0.04	0.5	20.0	0.1	0.1	N	2005	2008	2014	2017
Cuvier's beaked whale (California/Oregon/Washington)	3,274	0.67	2,059	0.04	0.5	21	<0.1	<0.1	N	2005	2008	2014	2017

Appendix 3. Pacific reports revised in 2017 are highlighted. S=strategic stock, N=non-strategic stock. unk=unknown, undet=undetermined, n/a=not applicable.

Species (Stock Area)	N est	CV N est	N min	R max	Fr	PBR	Total Annual Mortality + Serious Injury	Annual Fishery Mortality + Serious Injury	Strategic Status	Recent Abundance Surveys			SAR Last Revised
Pygmy Sperm whale (California/Oregon/Washington)	4,111	1.12	1,924	0.04	0.5	19.2	0	0	N	2005	2008	2014	2016
Dwarf sperm whale (California/Oregon/Washington)	unk	unk	unk	0.04	0.5	undet	0	0	N	2005	2008	2014	2016
Sperm whale (California/Oregon/Washington)	1,997	0.57	1,270	0.04	0.1	2.5	0.9	0.7	S	2005	2008	2014	2017
Gray whale (Eastern N Pacific)	20,990	0.05	20,125	0.062	1.0	624	132	4.25	N	2009	2010	2011	2014
Gray whale (Western N Pacific)	140	0.04	135	0.062	0.1	0.06			S			2011	2014
Humpback whale (California/Oregon/Washington)	1,918	0.03	1,876	0.08	0.3	11.0	≥ 9.2	≥ 7.6	S	2005	2008	2014	2017
Blue whale (Eastern N Pacific)	1,647	0.07	1,551	0.04	0.3	2.3	≥ 0.2	≥ 0.2	S	2005	2008	2011	2017
Fin whale (California/Oregon/Washington)	9,029	0.12	8,127	0.04	0.5	81	≥ 2.0	≥ 0.2	S	2005	2008	2014	2016
Sei whale (Eastern N Pacific)	519	0.4	374	0.04	0.1	0.75	0	0	S	2005	2008	2014	2016
Minke whale (California/Oregon/Washington)	636	0.72	369	0.04	0.48	3.5	≥ 1.3	≥ 1.3	N	2005	2008	2014	2016
Bryde's whale (Eastern Tropical Pacific)	unk	unk	unk	0.04	0.5	undet	unk	unk	N	n/a	n/a	n/a	2015
Rough-toothed dolphin (Hawaii)	72,528	0.39	52,833	0.04	0.5	423	2.1	2.1	N		2002	2010	2017
Rough-toothed dolphin (American Samoa)	unk	unk	unk	0.04	0.5	undet	unk	unk	unk	n/a	n/a	n/a	2010
Risso's dolphin (Hawaii)	11,613	0.43	8,210	0.04	0.5	82	0	0	N		2002	2010	2017
Common Bottlenose dolphin (Hawaii Pelagic)	21,815	0.57	13,957	0.04	0.5	140	0	0	N		2002	2010	2017
Common Bottlenose dolphin (Kaua'i and Ni'ihau)	n/a	n/a	97	0.04	0.5	1.0	unk	unk	N	2003	2012	2015	2017
Common Bottlenose dolphin (O'ahu)	n/a	n/a	n/a	0.04	0.5	undet	unk	unk	N	2002	2003	2006	2017
Common Bottlenose dolphin (4 Islands Region)	n/a	n/a	n/a	0.04	0.5	undet	unk	unk	N	2002	2003	2006	2017
Common Bottlenose dolphin (Hawaiian Island)	n/a	n/a	91	0.04	0.5	0.9	unk	unk	N	2002	2003	2006	2017
Pantropical Spotted dolphin (Hawaii Pelagic)	55,795	0.40	40,338	0.04	0.5	403.0	0	0	N		2002	2010	2017
Pantropical Spotted dolphin (O'ahu)	unk	unk	unk	0.04	0.5	undet	unk	unk	N			n/a	2017
Pantropical Spotted dolphin (4 Islands Region)	unk	unk	unk	0.04	0.5	undet	unk	unk	N			n/a	2017
Pantropical Spotted dolphin (Hawaii Island)	unk	unk	unk	0.04	0.5	undet	≥ 0.2	≥ 0.2	N			n/a	2017
Spinner dolphin (Hawaii Pelagic)	unk	unk	unk	0.04	0.5	undet	0	0	N		2002	2010	2013
Spinner dolphin (Hawaii Island)	631	0.04	585	0.04	0.5	5.9	unk	unk	N	1994	2003	2011	2013
Spinner dolphin (O'ahu / 4 Islands)	355	0.09	329	0.04	0.5	3.3	unk	unk	N	1993	1998	2007	2013
Spinner dolphin (Kaua'i / Ni'ihau)	601	0	509	0.04	0.5	5.1	unk	unk	N	1995	1998	2005	2013
Spinner dolphin (Kure / Midway)	unk	unk	unk	0.04	0.5	undet	unk	unk	N		1998	2010	2013
Spinner dolphin (Pearl and Hermes Reef)	unk	unk	unk	0.04	0.5	undet	unk	unk	N			n/a	2013
Spinner dolphin (American Samoa)	unk	unk	unk	0.04	0.5	undet	unk	unk	unk			n/a	2010
Striped dolphin (Hawaii Pelagic)	61,021	0.38	44,922	0.04	0.5	449	0	0	N		2002	2010	2017
Fraser's dolphin (Hawaii)	51,491	0.66	31,034	0.04	0.5	310	0	0	N		2002	2010	2017
Melon-headed whale (Hawaiian Islands)	8,666	1.00	4,299	0.04	0.5	43	0	0	N		2002	2010	2017
Melon-headed whale (Kohala Resident)	447	0.12	404	0.04	0.5	4.0	0	0	N			2009	2013
Pygmy killer whale (Hawaii)	10,640	0.53	6,998	0.04	0.4	56.0	1.1	1.1	N		2002	2010	2017

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Species (Stock Area)	N est	CV N est	N min	R max	Fr	PBR	Total Annual Mortality + Serious Injury	Annual Fishery Mortality + Serious Injury	Strategic Status	Recent Abundance Surveys				SAR Last Revised
False killer whale (NW Hawaiian Islands)	617	1.11	290	0.04	0.4	2.3	0.4	0.4	N				2010	2017
False killer whale (Hawaii Pelagic)	1,540	0.66	928	0.04	0.5	9.3	7.6	7.6	N		2002		2010	2017
False killer whale (Palmyra Atoll)	1,329	0.65	806	0.04	0.4	6.4	0.3	0.3	N				2005	2013
False killer whale (Main Hawaiian Islands Insular)	167	0.14	149	0.04	0.1	0.30	0.0	0.0	S	2013	2014	2015		2017
False killer whale (American Samoa)	unk	unk	unk	0.04	0.5	undet	unk	unk	unk	n/a	n/a	n/a		2010
Killer whale (Hawaii)	146	0.96	74	0.04	0.5	0.7	0	0	N		2002		2010	2017
Pilot whale, short-finned (Hawaii)	19,503	0.49	13,197	0.04	0.4	106	0.9	0.9	N		2002		2010	2017
Blainville's beaked whale (Hawaii Pelagic)	2,105	1.13	980	0.04	0.5	10.0	0	0	N		2002		2010	2017
Longman's Beaked Whale (Hawaii)	7,619	0.66	4,592	0.04	0.5	46.0	0	0	N		2002		2010	2017
Cuvier's beaked whale (Hawaii Pelagic)	723	0.69	428	0.04	0.5	4.3	0	0	N		2002		2010	2017
Pygmy sperm whale (Hawaii)	unk	unk	unk	0.04	0.5	undet	0	0	N		2002		2010	2013
Dwarf sperm whale (Hawaii)	unk	unk	unk	0.04	0.5	undet	0	0	N		2002		2010	2013
Sperm whale (Hawaii)	4,559	0.33	3,478	0.04	0.1	13.9	0.7	0.7	S		2002		2010	2017
Blue whale (Central N Pacific)	133	1.09	63	0.04	0.1	0.1	0	0	S		2002		2010	2017
Fin whale (Hawaii)	154	1.05	75	0.04	0.1	0.1	0	0	S		2002		2010	2017
Bryde's whale (Hawaii)	1,751	0.29	1,378	0.04	0.5	13.8	0	0	N		2002		2010	2017
Sei whale (Hawaii)	391	0.90	204	0.04	0.1	0.4	0.2	0.2	S		2002		2010	2017
Minke whale (Hawaii)	unk	unk	unk	0.04	0.5	undet	0	0	N		2002		2010	2013
Humpback whale (American Samoa)	unk	unk	150	0.106	0.1	0.4	0	0	S	2006	2007	2008		2009
Sea Otter (Southern)	2,826	n/a	2,723	0.06	0.1	8	≥0.8	≥0.8	S	2006	2007	2008		2008
Sea Otter (Washington)	n/a	n/a	1,125	0.2	0.1	11	≥0.2	≥0.2	N	2006	2007	2008		2008