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BRYDE'S WHALE (*Balaenoptera edeni*): Hawai'i Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

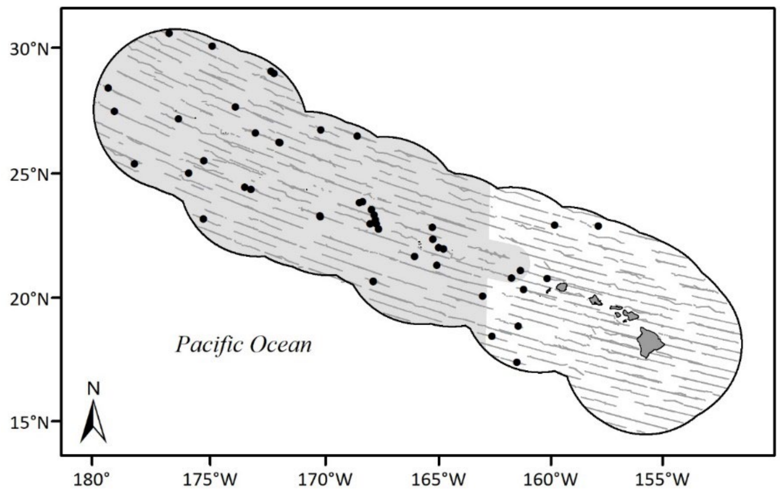

Figure 1. Bryde's whale sighting locations (circles) and survey effort (gray lines) during the 2002 (Barlow 2006), 2010 (Bradford *et al.* 2017), and 2017 (Yano *et al. 2018*) shipboard surveys of the U.S. EEZ around the Hawaiian Islands (outer black line). The Papahānaumokuākea Marine National Monument in the western portion of the EEZ is shaded gray.

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 Hawai'i and around Midway Island. 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). Periodic shipboard surveys of the waters within the U.S. Exclusive Economic Zone (EEZ) of the Hawaiian Islands have regularly encountered Bryde's whales throughout the EEZ (Figure 1). 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).

For the Marine Mammal Protection Act (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 150ºW and including the Gulf of California and waters off California). The Hawai'i 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 of the Hawaiian Islands (NMFS 2005).

POPULATION SIZE

Encounter data from shipboard line-transect surveys of the Hawaiian Islands EEZ were recently reevaluated for each survey year, resulting in updated model-based abundance estimates of Bryde's whales in the entirety of the Hawaiian Islands EEZ (Becker *et al.* 2021, 2022) (Table 1).

Sighting data from 2002 to 2020 within the Hawaiian Islands EEZ were used to derive habitat-based models of animal density for two periods: 2002-2017 (Becker et al. 2021) and 2017-2020 (Becker *et al*. 2022). The most recent set of models include three notable changes from the 2002-2017 models: use of calibrated group size estimates, as in Bradford *et al*. (2021), exclusion of a spatial term on model selection, requiring more explicit reliance on environmental variables, and incorporating new approaches (Miller *et al*. 2022) for more comprehensively estimating uncertainty in model predictions that account for the combined uncertainty around all parameter estimates. The modeling framework incorporated Beaufort-specific trackline detection probabilities for Bryde's whales from Barlow *et al*. (2015). Models were used to predict density and abundance for each survey year based on the environmental conditions within that year (see Forney *et al.* 2015, Becker *et al.* 2016).

Table 1. Model-based line-transect abundance estimates for Bryde's whales in the Hawaiian Islands EEZ in 2002 and 2010 (Becker *et al.* 2021) and 2017 and 2020 (Becker *et al*. 2022), derived from NMFS surveys in the central Pacific

since 2000. The Becker *et al*. (2022) analysis incorporates a more comprehensive model-based approach to estimating model uncertainty, such that the CVs and 95% confidence limits for 2002/2010 and 2017/2020 are not directly comparable.

Year	Model-based Abundance	CV	95% Confidence Limits
2020	791	0.29	456-1,372
2017	679	0.29	392-1,175
2010	822	0.20	554-1,220
2002	562	0.21	375-842

Bradford *et al.* (2021) produced design-based abundance estimates for Bryde's whales in 2002, 2010, and 2017 that can be used as a point of comparison to the model-based estimates for those years. While on average, the estimates are broadly similar between the two approaches, the annual design-based estimates show much greater variability between years than do the model-based estimates (Figure 2). The model-based approach reduces variability through explicit examination of habitat relationships across the full dataset, while the design-based approach evaluates encounter data for each year separately and thus is more susceptible to the effects of encounter rate variation. Bradford *et al.* (2021) found through simulation that the pronounced decrease in the design-based estimates between 2010 and 2017 could not be explained by encounter rate variation alone and likely reflected true changes in distribution of Bryde's whales in the study area between those survey years. The model based-estimates demonstrated a much smaller decrease between 2010 and 2017, but are based on the implicit assumption that changes in abundance are attributed to environmental variability alone. Explicitly incorporating a trend term into the model is not possible due to the insufficient sample size to test for temporal effects. Despite not fully accounting for inter-annual variation in total abundance, the model-based estimates are considered the best available estimate for each survey year. Previously published abundance estimates for the Hawaiian Islands EEZ (Barlow 2006, Becker *et al.* 2012, Forney *et al.* 2015, Bradford *et al.* 2017) used a subset of the dataset used by Becker *et al.* (2021, 2022) and Bradford *et al.* (2021) to derive line-transect parameters, such that these estimates have been superseded by the estimates presented here. The best estimate of abundance is based on the 2020 survey, or 791 (CV=0.29) Bryde's whales.

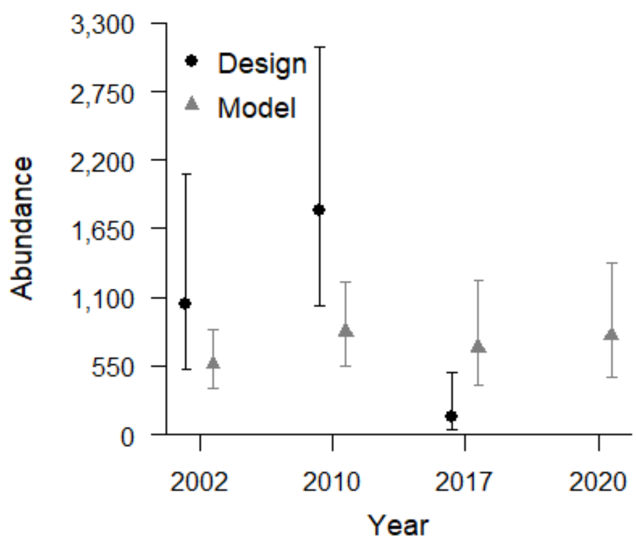

Figure 2. Comparison of design-based (black circles, Bradford *et al.* 2021) and model-based (gray triangles, Becker *et al.* 2021, 2022) estimates of abundance for Hawai‘i Bryde's whales for each survey year (2002, 2010, 2017, 2020).

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

The minimum population estimate is calculated as the lower 20th percentile of the log-normal distribution (Barlow *et al.* 1995) of the 2020 abundance estimate (Becker *et al.* 2022), or 623 Bryde's whales.

Current Population Trend

The model-based abundance estimates for Bryde's whales provided by Becker *et al.* (2021, 2022) do not explicitly allow for examination of population trend other than that driven by environmental factors. Although annual encounter rate variation may have a large impact on abundance estimates for species with low density and patchy distribution, Bradford *et al.* (2021) suggest that the very high sighting rate in 2010 and very low sighting rate in 2017 cannot be explained through encounter rate variation alone and that there may be true fluctuations in Bryde's whale abundance within the Hawaiian Islands EEZ. Model-based examination of Bryde's whale population trends including sighting data beyond the Hawaiian Islands EEZ will be required to more fully examine trend for this 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 stock of Bryde's whales is calculated as the minimum population size within the U.S EEZ of the Hawaiian Islands (623) 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 6.2 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, but are prohibited from operating within the Papahānaumokuākea Marine National Monument (PMNM) and within the Longline Exclusion Zone around the main Hawaiian Islands and the Pacific Remote Islands and Atolls (PRIA) MNM around Johnston Atoll. The PMNM originally included the waters within a 50 nmi radius around the Northwestern Hawaiian Islands. In August, 2016, the PMNM area was expanded to extend to the 200 nmi EEZ boundary west of 163° W. Between 2017 and 2021, no Bryde's whales were observed hooked or entangled in the SSLL fishery (100% observer coverage) or the DSLL fishery (15-21% observer coverage) (McCracken and Cooper 2022). Balaenopterid whales have been observed entangled in longline gear off the Hawaiian Islands in the past (Bradford 2018).

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 Hawai'i 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 large whales (Richardson *et al.* 1995, Weilgart 2007).

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