**A proposal for new stock boundaries for bottlenose dolphins in the Hawaiian EEZ**

Karen K. Martien[1] and Robin W. Baird[2]

[1]Southwest Fisheries Science Center, La Jolla, CA
[2]Cascadia Research Collective, Olympia, WA

Common bottlenose dolphins (*Tursiops truncatus*) are found in temperate and tropical waters throughout the world. Common bottlenose dolphins (hereafter bottlenose dolphins) are highly social and have been found to exhibit high degrees of population structuring over relatively small spatial scales in many parts of their range. Distinct coastal and offshore forms have been documented in the Northwest Atlantic, Gulf of Mexico, British Isles, Gulf of California, and eastern North Pacific (Curry, 1997; Hoelzel *et al.*, 1998; Lowther, 2006; Natoli *et al.*, 2004; Parsons *et al.*, 2002; Sanino *et al.*, 2005; Segura *et al.*, 2006).

The current Marine Mammal Protection Act (MMPA) stock assessment report (SAR) recognizes a single stock of bottlenose dolphins within the Hawaiian Exclusive Economic Zone (EEZ). However, recent photo-identification (Baird *et al.*, 2009) and genetic (Martien *et al.*, in review) studies have revealed evidence of multiple, demographically-independent populations of bottlenose dolphins within the Hawaiian EEZ. We summarize those studies and propose four new, insular stocks of bottlenose dolphins.

**Photo-identification data**

Baird *et al*. (2009) conducted a photo-identification study around the four main Hawaiian Island groups (Kauaʻi and Niʻihau, Oʻahu, the ʻ4-islands region (Maui, Molokaʻi, Lanaʻi, and Kahoʻolawe), and Hawaiʻi) from 2000 to 2006. Both within-year and between-year re-sighting rates were high at most island groups, indicating the presence of resident insular populations. Nearly all (99.3%) sightings occurred in water less than 1000 m deep, despite the fact that nearly half of the effort was in depths greater than 1000 m (Fig. 1), further supporting the conclusion that the dolphins are resident to the islands rather than part of an offshore population.

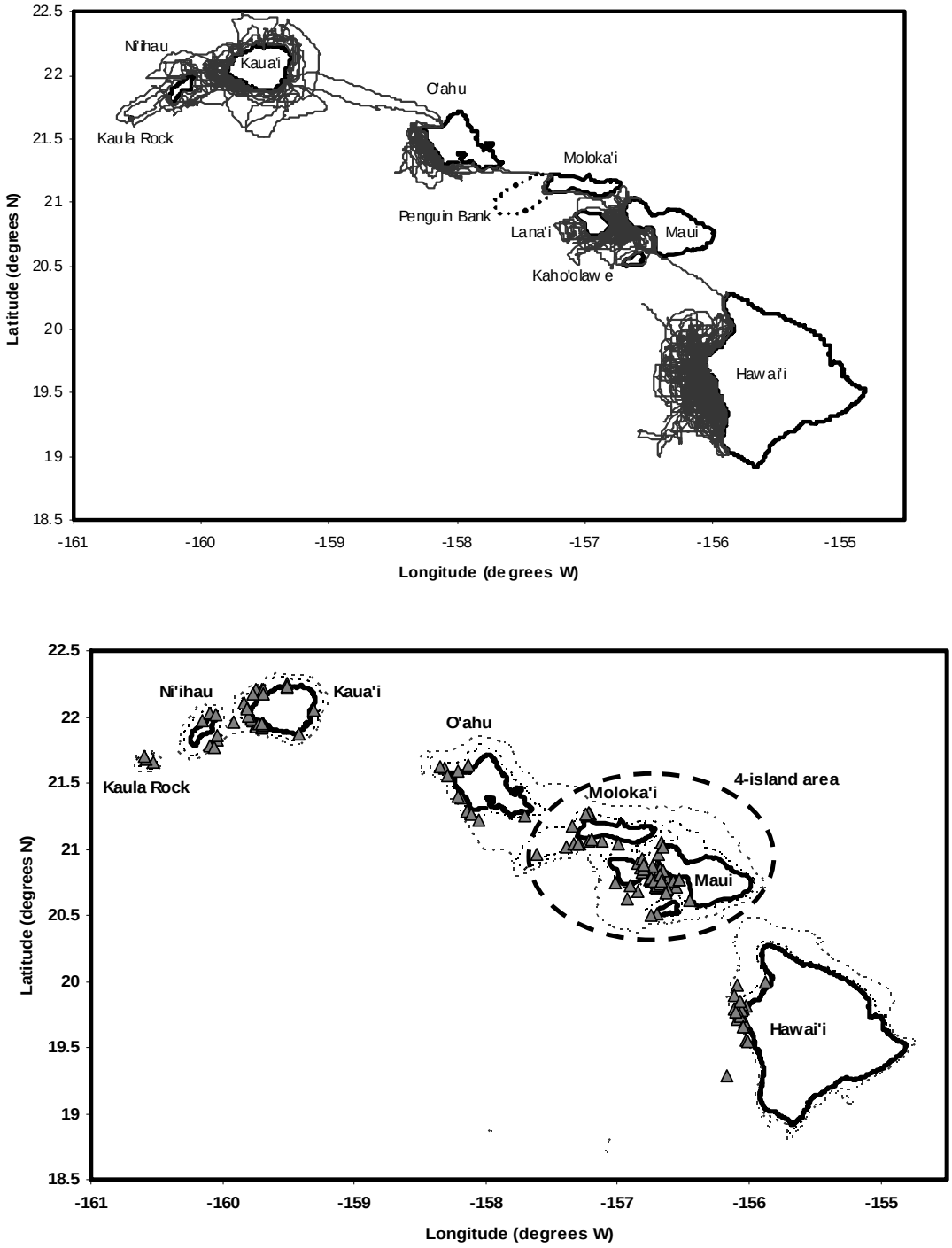


Figure 1 (From Baird *et al.*, 2009). Top: Distribution of search effort from directed odontocete surveys. Opportunistic efforts were in areas that were also surveyed in directed efforts, with the exception of Penguin Bank, indicated, where additional opportunistic surveys were undertaken. Bottom: Bottlenose dolphin sightings from which usable photo-identifications were obtained. The 200 m and 1,000 m depth contours are shown.

No inter-island movements of identified dolphins were detected during the course of Baird *et al.*'s (2009) study. A Bayesian analysis of the sightings data indicated that the annual inter-

island dispersal rate is less than 1%, which is low enough to necessitate management as separate stocks if the goals of the MMPA are to be met (Angliss and Wade, 1997; Taylor, 1997).

**Genetic data**

Martien *et al*. (in review) investigated population structure around the main Hawaiian Islands using 400 base pairs of mitochondrial sequence and 11 nuclear microsatellite loci from 137 individual dolphins (Fig. 2). Their analysis of the mitochondrial data revealed significant differentiation between the 4-islands region and the other island groups (Table 1), while their microsatellite data exhibited significant differentiation between all pairs of island groups (Table 2). Martien *et al*. also found strong differentiation between each of the Hawaiian Island groups and samples collected near Palmyra.

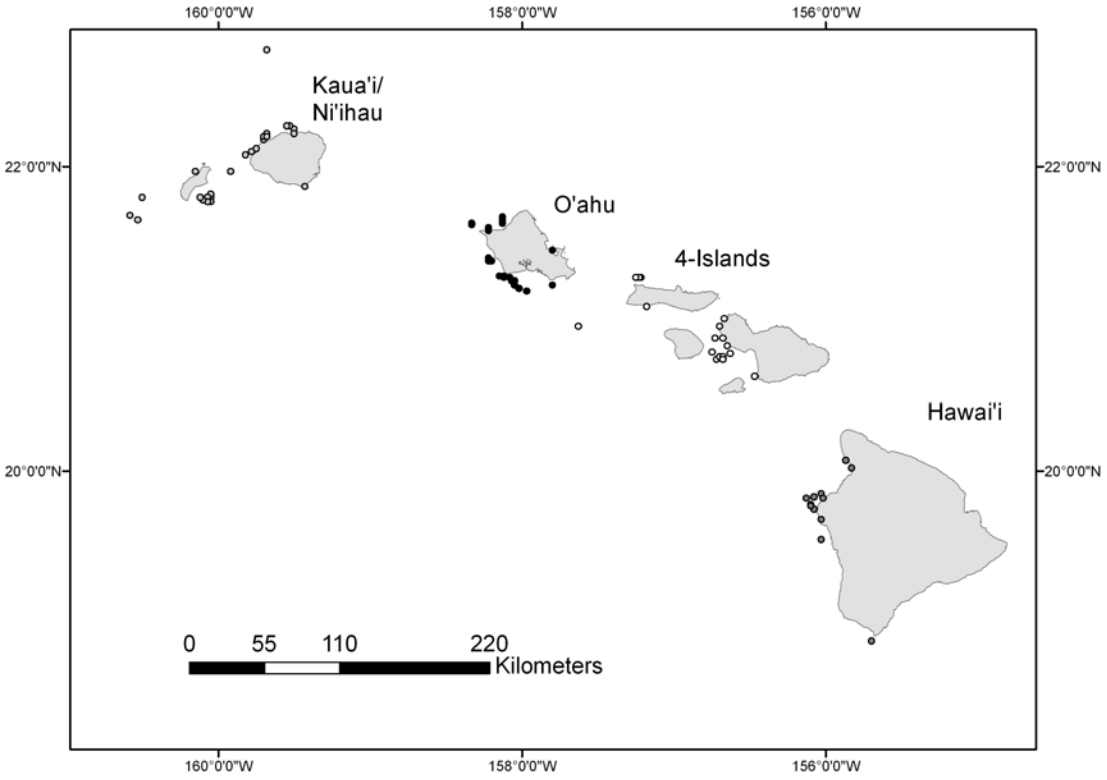


Figure 2 (From Martien *et al*., in review). Locations of samples used in genetic analysis of population structure. Samples are shaded to indicate the island group to which they belong.

Table 1. Pairwise differentiation between the island groups for mtDNA sequence data with sample size in parentheses. $F_{ST}$ (*p*-value in parentheses) is below the diagonal, while the *p*-values from the Fisher's exact tests are above the diagonal. Comparisons that are statistically significant at the $\alpha$=0.05 level are in bold.

| | Palmyra (11) | Hawai'i (21) | 4-Islands (26) | O'ahu (30) | Kaua'i/Ni'ihau (40) |
|---|---|---|---|---|---|
| Palmyra (11) | -- | **0.005** | **<0.001** | **<0.001** | **<0.001** |
| Hawai'i (21) | **0.074 (0.012)** | -- | **0.006** | 0.188 | 0.180 |
| 4-Islands (26) | **0.164 (0.0004)** | **0.071 (0.014)** | -- | **<0.001** | **0.017** |
| O'ahu (30) | **0.130 (0.0006)** | -0.008 (0.571) | **0.083 (0.004)** | -- | 0.170 |
| Kaua'i/Ni'ihau (40) | **0.104 (0.0012)** | -0.0002 (0.419) | **0.045 (0.019)** | 0.001 (0.377) | -- |

Table 2. Pairwise differentiation between the island groups for microsatellite data with sample size in parentheses. $F_{ST}$ (*p*-value in parentheses) is below the diagonal, while the *p*-values from the G-tests are above the diagonal. Comparisons that are statistically significant at the $\alpha$=0.05 level are in bold.

| | Palmyra (11) | Hawai'i (21) | 4-Islands (26) | O'ahu (30) | Kaua'i/Ni'ihau (40) |
|---|---|---|---|---|---|
| Palmyra (11) | -- | **0.001** | **0.001** | **0.001** | **0.001** |
| Hawai'i (21) | **0.084 (<0.001)** | -- | **0.005** | **0.002** | **0.008** |
| 4-Islands (26) | **0.096 (<0.001)** | **0.014 (0.015)** | -- | **0.007** | **0.001** |
| O'ahu (30) | **0.082 (<0.001)** | **0.013 (0.016)** | 0.0052 (0.140) | -- | **0.012** |
| Kaua'i/Ni'ihau (40) | **0.083 (<0.001)** | **0.011 (0.013)** | **0.007 (0.035)** | **0.008 (0.024)** | -- |

Martien *et al*. (in review) found evidence of a broadly-distributed pelagic population utilizing the waters around the main Hawaiian Islands. Specifically, in an assignment test, six individuals sampled around the main Hawaiian Islands clustered with animals sampled near Palmyra rather than with the other Hawaiian animals. Four of the six were sampled together in deep water (>400 m) off the southern tip of the island of Hawai'i during an SWFSC cruise, and were the only animals sampled around the main Hawaiian Islands that shared haplotypes with Palmyra. The other two individuals were both sampled in deep water by Baird *et al*. (2009) from groups that were not linked by association to any other individuals documented off the respective islands. Of the 17 samples assigned to this 'Palmyra' cluster (all 11 Palmyran samples and 6 from the Hawaiian Islands), 11 had haplotypes that are also present in the western Pacific (Tezanos-Pinto *et al.*, 2009). In contrast, only 10% (11 out of 111) of the remaining Hawaiian Islands samples possessed haplotypes detected elsewhere in the Pacific.

Based on these data, Martien *et al*. (in review) concluded that the six Hawaiian samples that clustered with Palmyra represent an additional, non-island associated population that occurs within the Hawaiian EEZ. Martien *et al*. did not have sufficient data to determine whether the Hawaiian pelagic samples and Palmyran samples belong to the same pelagic population or represent two separate pelagic populations that are more similar to each other than they are to the Hawaiian Island resident populations.

**Stock Proposal**

Based on the high degree of site fidelity evinced by the photo-identification data and the strong genetic differentiation between island groups, we propose that the current Hawaiian bottlenose dolphin stock be divided into the following five stocks: 1) Kauaʻi/Niʻihau Stock, 2) Oʻahu Stock, 3) 4-Islands Region Stock, 4) Hawaiʻi Island Stock, and 5) Hawaiian Pelagic Stock. The boundaries of the Kauaʻi/Niʻihau Stock and Hawaiʻi Island Stock will correspond to the 1000m isobath surrounding each of these island group (Fig. 3). The outer boundaries of the Oʻahu and 4-Islands Region Stocks will also correspond to the 1000m isobath. However, since that isobath does not separate the two island groups, the boundary between those stocks would run approximately equidistant between the 500 m isobaths around Oʻahu and the 4-Islands Region, through the middle of Kaʻiwi Channel (Fig. 3). The Hawaiian Pelagic Stock will encompass the entire Hawaiian EEZ not contained by one of the insular stocks.

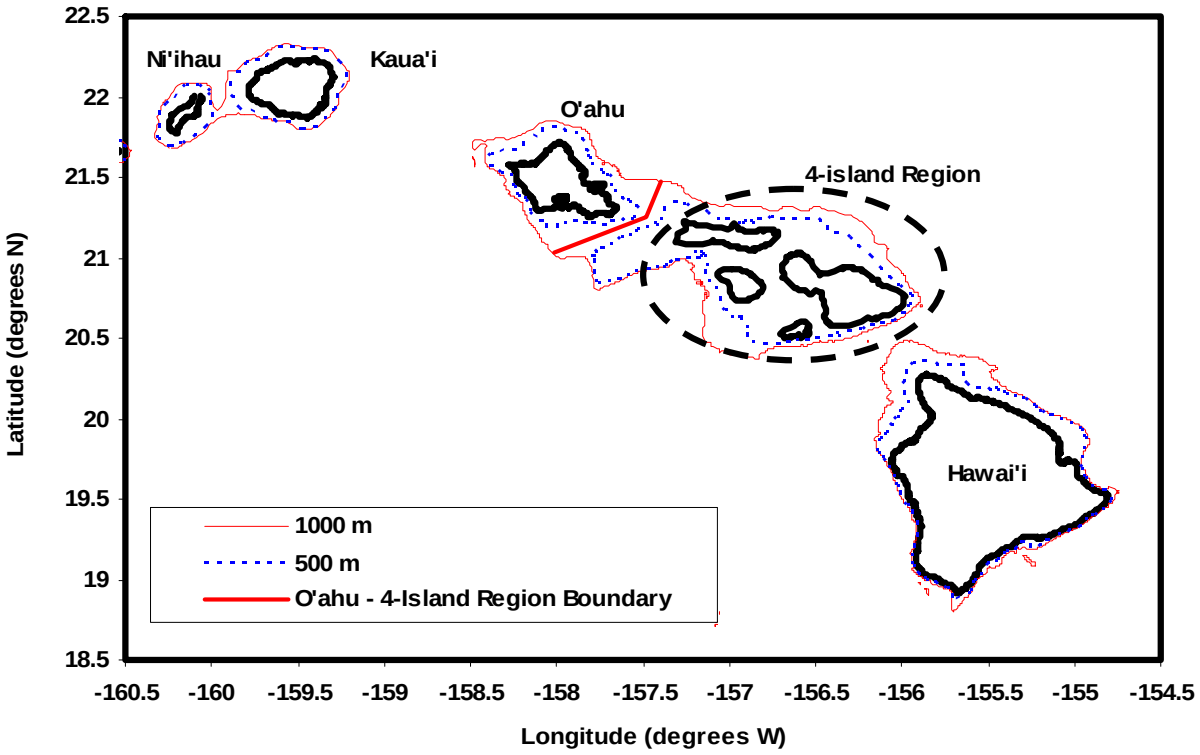


Figure 3. Proposed boundaries of insular stocks (red lines). The boundaries are comprised of the 1000m isobath plus a boundary between the Oʻahu and the 4-Island Region Stocks placed midway between the 500m isobaths surrounding these island groups.

The choice of the 1000m isobath for delineating the insular stocks is based on the fact that all but one of the 142 sightings of insular bottlenose dolphins recorded by Baird *et al*. (2009) occurred in depths of less than 1000m. The genetic data indicate that there is some degree of overlap between the ranges of the pelagic and insular populations, as two of the animals identified as belonging to the pelagic population by the genetic assignment test were found inside the 1000m isobath (Martien *et al.*, in review). The 1000m isobath was chosen to encompass nearly the entire known range of the insular stocks. However, this boundary may be revised as additional data become available. The situation around the Hawaiian Islands may be similar to that in the

western North Atlantic, where the ranges of the offshore and coastal ecotypes of bottlenose dolphins have a zone of overlap that is defined by both depth and distance from shore (Torres *et al.*, 2003).

Photo-identification efforts on Penguin Bank west of Moloka‘i have been limited (Baird et al. 2009). Penguin Bank has been included in the 4-islands Region Stock because it is separated from O‘ahu by the deep Ka‘iwi Channel. However, the boundary between O‘ahu and the 4-islands Region Stocks may be revised as additional data become available.

To date there have been no studies of bottlenose dolphins around the Northwest Hawaiian Islands (NWHI). In the absence of data on population structure in this area, animals from the NWHI have been included in the Hawaiian Pelagic Stock. However, given the existence of 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 (e.g., Andrews *et al.*, 2006; Hill *et al.*, 2009; Karczmarski *et al.*, 2005) it is likely that additional demographically independent populations of bottlenose dolphins exist in the NWHI. Additional research in this area is needed, and will likely result in the definition of additional bottlenose dolphin stocks.

**Literature Cited**


Andrews K.R., Karczmarski L., Au W.W.L., Rickards S.H., Vanderlip C.A., Toonen R.J. 2006. Patterns of genetic diversity of the Hawaiian spinner dolphin (*Stenella longirostris*). Atoll Research Bulletin Proceedings of the Northwestern Hawaiian Islands Third Symposium.

Angliss R., Wade P.R. 1997. Guidelines for assessing marine mammal stocks: report of the GAMMS Workshop, April 3-5, 1996, Seattle, WA.

Baird R.W., Gorgone A.M., McSweeney D.J., Ligon A.D., Deakos M.H., Webster D.L., Schorr G.S., Martien K.K., Salden D.R., Mahaffy S.D. 2009. Population structure of island-associated dolphins: Evidence from photo-identification of common bottlenose dolphins (*Tursiops truncatus*) in the main Hawaiian Islands. *Marine Mammal Science* 25:251-274.

Curry B.E. 1997. Phylogenetic relationships among bottlenose dolphins (Genus *Tursiops*) in a worldwide context (M. Sc.): Texas A&M University.

Hill M.C., Oleson E.M., Andrews K.R. 2009. A proposal for new spinner dolphin stock boundaries in Hawai'i and a new stock in American Samoa. Paper PSRG-2009-12 presented to the Pacific Scientific Review Group, San Diego, CA, November 2009.

Hoelzel A.R., Potter C.W., Best P.B. 1998. Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. *Proceedings of the Royal Society of London, B* 265:1177-1183.

Karczmarski L., Wursig B., Gailey G., Larson K.W., Vanderlip C. 2005. Spinner dolphins in a remote Hawaiian atoll: social grouping and population structure. *Behavioral Ecology* 16:675-685.

Lowther J.L. 2006. Genetic variation of coastal and offshore bottlenose dolphins, *Tursiops truncatus*, in the eastern North Pacific ocean (M. Sc.): University of San Diego.

Martien K.K., Baird R.W., Hedrick N.M., Gorgone A.M., Thieleking J.L., McSweeney D.J., Robertson K.M., Webster D.L. in review. Population structure of island-associated dolphins: evidence from mitochondrial and microsatellite markers for common bottlenose

dolphins (*Tursiops truncatus*) around the main Hawaiian Islands. *Marine Mammal Science*.

Natoli A., Peddemors V.M., Hoelzel A.R. 2004. Population structure and speciation in the genus *Tursiops* based on microsatellite and mitochondrial DNA analyses. *Journal of Evolutionary Biology* 17:363-375.

Parsons K.M., Noble L.R., Reid R.J., Thompson P.M. 2002. Mitochondrial genetic diversity and population structuring of UK bottlenose dolphins (*Tursiops truncatus*): is the NE Scotland population demographically and geographically isolated? *Biological Conservation* 108:175-182.

Sanino G.P., Van Waerebeek K., Van Bressem M.-F., Pastene L.A. 2005. A preliminary note on population structure in eastern South Pacific common bottlenose dolphins, *Tursiops truncatus*. *J. Cetacean Res. Manage.* 6:65-70.

Segura I., Rocha-Olivares A., Flores-Ramirez S., Rojas-Bracho L. 2006. Conservation implications of the genetic and ecological distinction of *Tursiops truncatus* ecotypes in the Gulf of California. *Biological Conservation* 133:336-346.

Taylor B.L. 1997. Defining "population" to meet management objectives for marine mammals. *In*: A.E. Dizon, S.J. Chivers, W.F. Perrin eds.) *Molecular genetics of marine mammals*. Society for Marine Mammalogy, Special Publication 3, Lawrence, KS. 49-65.

Tezanos-Pinto G., Baker C.S., Russell K., Martien K., Baird R.W., Hutt A., Stone G., Mignucci-Giannoni A.A., Caballero S., Endo T., Lavery S., Oremus M., Olavarria C., Garrigue C. 2009. A Worldwide Perspective on the Population Structure and Genetic Diversity of Bottlenose Dolphins (*Tursiops truncatus*) in New Zealand. *Journal of Heredity* 100:11-24.

Torres L.G., Rosel P.E., D'Agrosa C., Read A.J. 2003. Improving management of overlapping bottlenose dolphin ecotypes through spatial analysis and genetics. *Marine Mammal Science* 19(3):502-514.