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Migratory destinations of endangered humpback whales, *Megaptera novaeangliae* (Cetartiodactyla: Balaenopteridae), from El Salvador

Nicola Ransome^{1, 2, 3*},  <https://orcid.org/0000-0002-3130-3966>

Melvin G. Castaneda^{1, 2},  <https://orcid.org/0000-0001-7559-1042>

Ted Cheeseman^{4, 5},  <https://orcid.org/0000-0002-5805-2431>

John Calambokidis⁶,  <https://orcid.org/0000-0002-5028-7172>

Fred Sharpe⁷,  <https://orcid.org/0000-0002-6256-5547>

1. Proyecto Megaptera El Salvador, Los Cóbano, Sonsonate, El Salvador; melvingiocastaneda@gmail.com
2. Fundación Naturaleza El Salvador, San Salvador, El Salvador; fundanaturaleza@gmail.com
3. Harry Butler Institute, Environmental and Conservation Sciences, College of Science, Health, Engineering and Education, Murdoch University, Western Australia, Australia; nicola.ransome@murdoch.edu.au (*Correspondence).
4. Marine Ecology Research Centre, Southern Cross University, Lismore, New South Wales, Australia
5. Happywhale, Santa Cruz, California, US; ted@happywhale.com
6. Cascadia Research Collective, Olympia, Washington, US; calambokidis@cascadiaresearch.org
7. Alaska Whale Foundation, Petersburg, Alaska, US; fsharpe@alaskawhalefoundation.org

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ABSTRACT

Introduction: The study of many aspects of cetacean ecology is made possible by identifying individuals through space and time. Humpback whales (*Megaptera novaeangliae*) can be easily identified by photographing their ventral tail flukes' unique shape and pigmentation patterns. The small and endangered distinct population segment (DPS) of Central America humpback whales visit El Salvador seasonally each winter; however, dedicated research has been extremely limited there. Before 2018, only 11 individual whales had been photo-identified, and the migratory destinations of Salvadoran humpback whales were unknown. In recent years, photo-identification efforts have increased, and today there are 92 individually identified humpback whales from El Salvador.

Objective: To identify the main high-latitude feeding areas of Salvadoran humpback whales.

Methods: Using the online matching platform Happywhale, Salvadoran whales were matched via automated image recognition to a global humpback whale fluke photo-identification catalog of 66 043 individuals.

Results: In total, 80 (87.0 %) of the whales photographed in El Salvador were matched to individuals seen in North Pacific feeding areas. Sighting histories of Salvadoran whales resighted in feeding areas ranged from two to 29 years (average = 12.1, SD = 5.8). While we note that survey effort was likely very different between regions, the main feeding area of Salvadoran humpback whales on Happywhale was Central California (n = 70, 76.1 %). Of these whales, 21 (22.8 %) had also been sighted in Southern California, while just three (3.3 %) individual whales were registered only in Southern California. Additionally, two whales (2.2 %) were sighted in Southern British Columbia, Canada, and one whale was matched to a humpback whale from Southeast Alaska. This whale (of unknown sex) has a sighting history of 27 years but no prior documentation in a breeding area and is the first published sighting of a Southeast Alaskan humpback whale in the breeding area of the endangered Central America DPS.

Conclusions: Our study shows that while Salvadoran humpback whales were matched to various feeding areas in the Eastern North Pacific, their primary migratory destinations are in Southern and Central California.



Key words: large whale conservation; endangered populations; migratory species; critical habitat protection; Central America distinct population segment.

RESUMEN

Destinos migratorios de ballenas jorobadas en peligro de extinción, *Megaptera novaeangliae* (Cetartiodactyla: Balaenopteridae), del El Salvador

Introducción: El estudio de muchos aspectos de la ecología de los cetáceos es posible gracias a la identificación de individuos a través del espacio y el tiempo. Las ballenas jorobadas (*Megaptera novaeangliae*) se pueden identificar fácilmente al fotografiar la forma única de la aleta caudal y el patrón de pigmentación de su lado ventral. Una parte del segmento de población distinta (DPS), pequeña y en peligro de extinción de las ballenas jorobadas de América Central visita estacionalmente cada invierno El Salvador, sin embargo, la investigación ha sido extremadamente limitada. Antes del 2018, solo existían imágenes de identificación de 11 ballenas individuales, y se desconocía el destino migratorio de las ballenas jorobadas salvadoreñas. En los últimos años, los esfuerzos de foto-identificación han aumentado, y hoy en día hay 92 ballenas jorobadas identificadas individualmente en El Salvador.

Objetivo: Identificar las principales áreas de alimentación en latitudes altas de las ballenas jorobadas salvadoreñas.

Métodos: Utilizando la plataforma en línea Happywhale, las aletas caudales de las ballenas de El Salvador fueron comparadas a través del reconocimiento automático de imágenes con un catálogo global de foto-identificación de 66 043 individuos.

Resultados: En total, 80 (87.0 %) de las ballenas fotografiadas en El Salvador se compararon con individuos vistos en las áreas de alimentación del Pacífico Norte. El historial de re-avistamientos de ballenas salvadoreñas en áreas de alimentación fluctuó de dos a 29 años (promedio = 12.1, d.e. = 5.8). La principal zona de alimentación para las ballenas jorobadas salvadoreñas fue el centro de California (n = 70, 76.1 %). De estas ballenas, 21 (22.8 %) también se habían avistado en el sur de California. Solo tres ballenas se habían visto (3.3 %) únicamente en el sur de California. Dos ballenas jorobadas (2.2 %) fueron avistadas en el sur de la Columbia Británica, Canadá, y lo más importante, una fue identificada como una ballena jorobada del sureste de Alaska. Esta ballena de sexo desconocido tiene un historial de avistamientos de 27 años, pero sin documentación previa en un área de reproducción. Este es el primer avistamiento publicado de una ballena jorobada del sudeste de Alaska en el DPS en peligro de extinción de América Central, y tal vez sea particularmente importante por razones de manejo.

Conclusiones: Este estudio encuentra que aunque las ballenas jorobadas que llegan a El Salvador se observan en varias localidades del Pacífico norte, su migración tiene como destino principal las aguas del Pacífico sur y central de California.

Palabras clave: conservación de ballenas; poblaciones en peligro; especies migratorias; protección de hábitat crítico; Segmento Poblacional Distinto de Central America.

INTRODUCTION

The humpback whale, *Megaptera novaeangliae* (Borowski, 1781) is a large migratory baleen whale with a cosmopolitan distribution, that typically migrates long distances between high-latitude summer feeding areas and low-latitude winter breeding areas (Dawbin, 1966). Their extensive annual migrations can be over 16 000 km round trips (Rasmussen et al., 2007; Stone et al., 1990), and therefore humpback whales of many worldwide populations will travel through the territorial waters of multiple countries each year. This creates challenges for developing management strategies for endangered and recovering populations and means

understanding migratory patterns and connections is critical for conservation. To aid with management, in 2016 the National Oceanic and Atmospheric Administration (NOAA) of the US government identified 14 main breeding regions of humpback whales for a worldwide status review, which they defined as having distinct population segments (DPSs) that visit to breed and calve each year; nine of these were classified as “Not at Risk”, one as “Threatened”, and only four as “Endangered” (Bettridge, 2015). The list of endangered DPSs included the Central America DPS of the North Pacific humpback whale, which was described as small and genetically distinct, and considered to be at moderate risk of extinction (Bettridge, 2015).

The study of many aspects of cetacean ecology is made possible by identifying individuals through space and time. Humpback whales can be easily identified by their ventral tail flukes' unique shape and pigmentation patterns (Katona & Whitehead, 1981). For the last five decades, photographic identification (e.g. photo-identification) of humpback whales and collaboration between international researchers has allowed for a growing understanding of the movements and migrations of humpback whale populations globally (Calambokidis et al., 2000, Calambokidis et al., 2001, Calambokidis et al., 2008; Cheeseman et al., 2021) However, worldwide there remain a few areas of seasonal habitat of the species where research has not been initiated. One such place was the Central American country of El Salvador, considered part of the breeding area of the Central America DPS. Whilst cetacean research was growing worldwide, El Salvador was in the midst of civil war, and dedicated cetacean surveying was extremely limited. Prior to 2018, only 11 individual humpback whales' fluke identification images existed, and therefore the migratory destinations of Salvadoran humpback whales were unknown. Increased photo-identification efforts began in the Pacific waters in 2018, and dedicated cetacean surveying was initiated in 2020. Here we present, for the first time, migratory connections of a significant number of Salvadoran humpback whales to North Pacific feeding areas, to aid in international management decisions and planning for the endangered Central America DPS.

Between 1999 and 2006, 11 photo-identification images of humpback whales were collected in the Pacific waters of El Salvador as part of Cascadia Research Collective research efforts throughout Central America (Calambokidis et al., 2008, Rasmussen et al., 2012). In 2006, a small whale-watching industry began in Los Cóbános, Sonsonate, El Salvador (Castaneda et al., 2021). In 2018, these tourism trips were then used as a research platform. Data collected included photo-identification images of humpback whales, Global Positioning System (GPS) tracks, and basic environmental

data (sea state, water temperature, cloud cover and visibility). In total, over 33 whale watch trips were conducted which resulted in over 109 hours of surveying, and 10 new photo-identification images. In 2020, 10 dedicated cetacean surveys were completed, involving 64 hours of surveying, encountering five groups of humpback whales and identifying seven individuals. In 2021, 41 research surveys were completed, of a total of 129 hours of surveys, 54 humpback whale groups were encountered, and 49 unique photo-identification images were collected. Since 2019, an additional 15 photo-identification images have also been collected on whale watch trips in the region.

All unique photo-identification images of individual humpback whales were uploaded to the research collaboration and citizen science web platform Happywhale (www.happy-whale.com). Individual whales were matched via automated image recognition to a global humpback whale fluke photo-identification catalog of 66043 individuals, of which 27 536 were identified in the North Pacific Ocean (Cheeseman et al., 2021). Images were matched with an expected accuracy of 97–99 % of potential matches found, match results were manually confirmed, and unmatched individuals with fluke identification photos of sufficient quality were considered new to the dataset and given an ID number. Great-circle distances between sighting locations of matched whales were then calculated using the methodology of Bowditch (1994).

Overall, 92 individual humpback whales have been identified in El Salvador between 1999–2021 during the boreal winter months, December through March. Via Happywhale, 80 (87.0 %) of the humpback whales photographed in El Salvador were matched to individuals seen in North Pacific feeding areas. No matches were made to areas outside of the North Pacific. Sighting histories of Salvadoran humpback whales resighted in feeding areas ranged from two to 29 years (average = 12.1, sd = 5.8).

The main feeding area where whales were resighted was Central California (n = 70, 76.1 %). Of these whales, 21 (22.8 %) had also

been sighted in Southern California. While only three (3.3 %) individually identified humpback whales were documented in just Southern California, and in no other feeding area. In total, 16 whales (17.4 %) had been sighted in Northern California, of which seven (8.8 %) had also been sighted in the centre of the state and five (6.3 %) in both Central California and Southern California. Two humpback whales (2.2 %) were sighted in Southern British Columbia, Canada, and most significantly, one individual photographed in El Salvador in 2021, was identified as a humpback whale that has been documented feeding in Southeast Alaska (SEAK) in multiple years (Fig. 1). In fact, this whale of unknown sex and named SEAK-5011, has been sighted five times over 27 years in SEAK, spanning four decades, being photographed in 1994, 2004 and 2021. Prior to 2021, SEAK-5011 had not been documented in a breeding area. On

5 February 2021, SEAK-5011 was seen in a group of two adult whales, near Los Cóbano, Sonsonate, El Salvador. That same year but after 196 days, SEAK-5011 was photographed in SEAK on the 20 August 2021, followed by another nearby sighting on 26 August 2021. Both feeding area observations were made in Frederick Sound, SEAK, and a minimum great-circle distance between the sightings from El Salvador and SEAK was calculated as approximately 6 100 km.

Previous studies have shown that humpback whales from the Central America DPS predominantly feed in the coastal waters of California (Calambokidis et al., 2000, Calambokidis et al., 2008; Rasmussen et al., 2012; Steiger et al., 1991). Our results support this finding with 83.7 % (77/92 whales) of whales photographed in El Salvador being matched to images taken in the waters of California, and

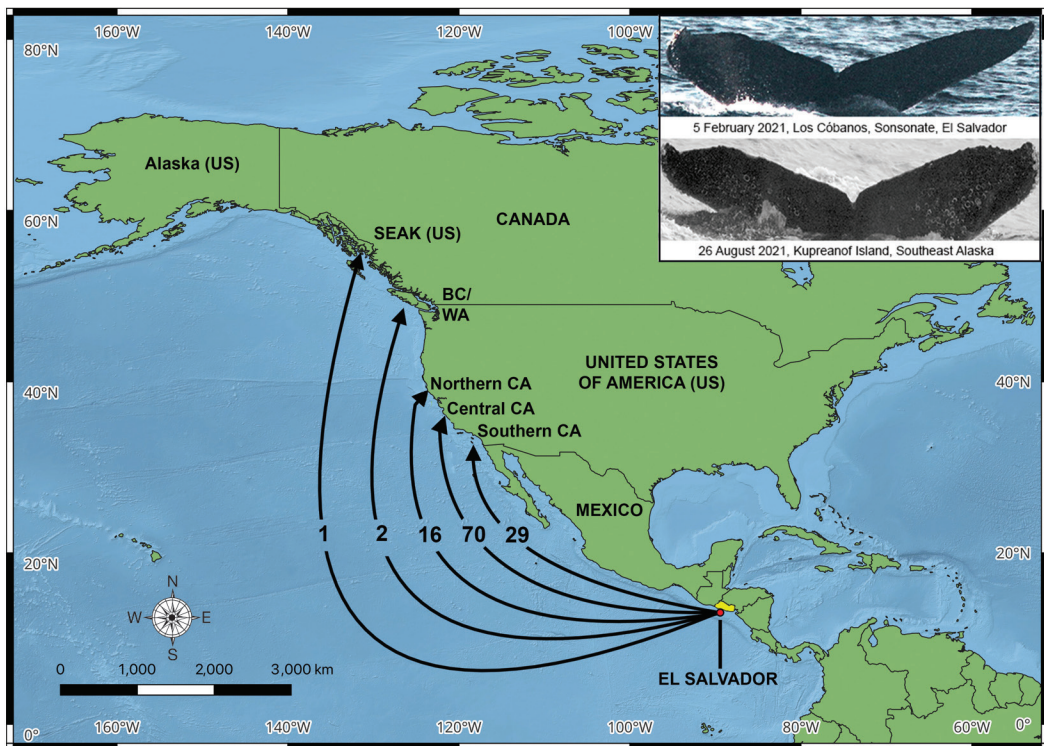


Fig. 1. Migratory connections of humpback whales from El Salvador. Numbers in arrows represent the number of individual whales matched between locations. Photo inset is of humpback whale SEAK-5011. CA= California, WA= Washington state (US), BC= British Columbia (Canada), SEAK = Southeast Alaska.

suggest that Southern and Central California are likely the most important feeding areas of humpback whales that winter in El Salvador. Our analysis found that nearly all Salvadorian humpback whales registered in Southern California (87.5 %, 21/24 whales) were also seen feeding in Central California. These results could be interpreted as implying the Southern California region is a transitory area to preferred feeding areas further north, rather than the terminal end of migration. However, we note that Happywhale effort is far greater in Central California (Author, Ted Cheeseman, Unpublished data), and also the possible source of these results.

The presence of humpback whales of the Central America DPS throughout the California feeding areas has particular significance to regional fishing regulations and management. Entanglement of humpback whales in gear of the California Dungeness crab pot fishery has increased at an alarming rate since 2014 (Lebon & Kelly, 2019), and has been demonstrated to reduce survivorship, particularly for juvenile humpback whales (Tackaberry et al., 2022). Large whales may travel thousands of kilometers carrying fishing gear and be entangled for many months, even years (Cassoff et al., 2011), and multiple entangled humpback whales have been encountered in El Salvador (Castaneda et al., 2022). In the US, the species is protected under the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). The continued documentation of the seasonal presence of the endangered Central America DPS in coastal California, an area where entanglement rates are high and increasing (Lebon & Kelly, 2019), should be a critical consideration for the future management of regional fisheries.

Our results also support previous findings (Calambokidis et al., 2000, Calambokidis et al., 2008), that a small number of humpback whales from the Central America DPS may be present in the more northern North Pacific feeding areas of Washington State (US) and British Columbia (Canada). Although matching attempts of humpback whale catalogs between North Pacific feeding areas and the

Central America DPS has been occurring since the 1990s (Calambokidis et al., 2000, Calambokidis et al., 2008; Rasmussen et al., 2012; Steiger et al., 1991), this is the first published report of a humpback whale photographed between Central America and SEAK. This has relevance for the management and protection of the SEAK feeding region of humpback whales. As part of the final rule of the Endangered Species Act published in April 2021, the United States' National Marine Fisheries Service (NMFS) recently delisted SEAK for humpback whales, stating that it was not 'Critical Habitat' for any of the endangered or threatened North Pacific DPSs. SEAK humpback whales are most commonly matched to the Hawaiian Archipelago (Calambokidis et al., 2008), a breeding region of a DPS classified as "Not at Risk" (Bettridge et al., 2015). The recapture of just one whale between SEAK to the endangered Central America DPS does not negate NMFS's "Not Critical" designation. However, the documentation of a whale in SEAK from a previously unsurveyed breeding region, combined with the fact that ~38 % of humpback whales that feed in SEAK are yet to be matched to breeding areas (Happywhale, unpublished data), lends to the possibility of more, as-of-yet undiscovered migratory connections between the two regions. If more matches are found between Central America and SEAK, it could have repercussions for future regional conservation and management planning in Alaska.

Lastly, our study shows the importance of initiating research efforts in unsurveyed areas of humpback whale habitat. This is especially true in breeding areas of the at risk (threatened and endangered) DPSs. Although SEAK-5011 has a sighting history of 27 years in the SEAK feeding areas, this adult whale had never before been documented in a breeding area. This is despite several decades of intensive photo-identification and matching efforts in the neighbouring Mexico DPS (Calambokidis et al., 2008, Cheeseman et al., 2021, Urbán et al., 2000) and predominantly the southern region of the Central America DPS (Steiger et al., 1991; Calambokidis et al., 2000, Calambokidis



et al., 2008; Rasmussen et al. 2012). Humpback whales have been shown to exhibit strong site-fidelity to seasonal breeding habitat in the North Pacific (Acebes et al., 2021; Herman et al., 2011). Therefore, this sighting of a SEAK humpback whale in a previously unsurveyed region of the breeding area of the endangered Central America DPS, highlights the need for expansion of research efforts to include all known humpback whale habitat. It also exemplifies the merit of the new research efforts that have been initiated in El Salvador, and the value of continued surveying and cetacean studies in the Pacific waters of this country.

Ethical statement: the authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgments section. A signed document has been filed in the journal archives.

Author Contribution: NR conceptualized this study, collected field data, analyzed the data, and drafted early and revised versions of this manuscript. MGC collected field data and edited the manuscript, TC curated photographic data and edited the manuscript, JC and FS collected and curated photographic data, and edited various versions of this manuscript.

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