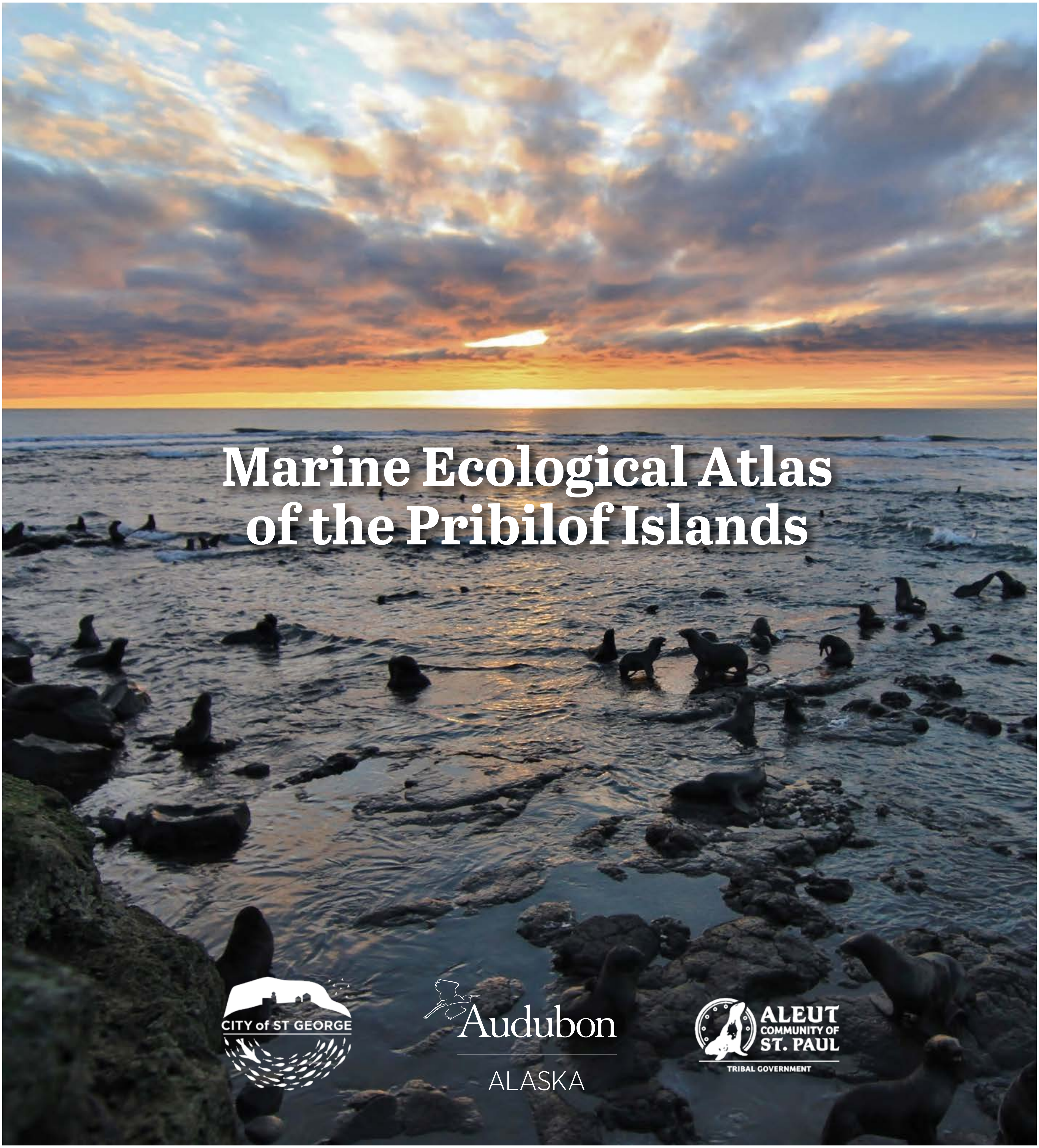
Marine Ecological Atlas of the Pribilof Islands



Paviilax


H. McFarland

Marine Ecological Atlas of the Pribilof Islands

Suggested Citation

Goldman, M. S., L. M. Divine, E. J. Knight, V. M. Padula, and D. P. Huffman. 2020. Marine Ecological Atlas of the Pribilof Islands. Audubon Alaska, Anchorage, AK.

Contents

Overview

MAPS

M. Goldman

Introduction

The Pribilof Islands, Alaska are centrally located in the Bering Sea, situated 200 miles (320 km) north of the nearest landmass, Unalaska Island in the Aleutian Islands chain, and 750 miles (1205 km) from Anchorage, Alaska. The Pribilofs consist of five islands: St. Paul and St. George, which support Indigenous Unangan (Aleut) communities, while Otter Island, Walrus Island, and Sea Lion Rock are uninhabited. The rich and diverse abundance of wildlife drawn to the Pribilof Islands are attracted by productive waters that result from a unique combination of currents and upwellings, the position of the islands archipelago near the historic maximum sea ice extent in the Bering Sea, and the remote location of these volcanic islands on the continental shelf that leads to the Aleutian Basin. The steep seaside cliffs and sloping rocky beaches that characterize the islands provide prime habitat for colonial-nesting seabirds and marine mammal haulouts and rookeries. The Pribilof Islands ecosystem also benefits from abundant primary production, often referred to as the Bering Sea green belt (Springer et al. 1996). Primary productivity is tied to the timing of annual sea ice retreat, the presence/absence of ice algae, the geographic location and bathymetry of the region, and water exchange between the Bering Sea and North Pacific Ocean, which supply nutrient- and plankton-rich waters from the outer shelf and slope through a zone of upwelling, forming the base of a robust and intricate food web (Brown and Arrigo 2013; Hunt et al. 2008; Sigler et al. 2014).

The biologically rich waters around the Pribilof Islands also nurture important Bering Sea commercial fisheries including walleye pollock (*Gadus chalcogrammus*), the largest commercial fishery in the nation, as well as Pacific halibut (*Hippoglossus stenolepis*), snow crab (*Chionoecetes opilio*) and red king crab (*Paralithodes camtschaticus*). The abundance of forage fish in the Pribilof Islands drives one of the highest densities of seabirds on the planet (Hood and Calder 1981). Seabirds time their return to the region from places as far as Antarctica and Australia to coincide with a surplus of available food abundance in the Pribilof Islands marine ecosystem. The significance of the region is apparent also in the substantial populations of murres (*Uria* spp.), auklets (*Aethia* spp.), puffins (*Fratercula* spp.), fulmars (*Fulmarus* spp.), storm-petrels (*Oceanodroma* spp.), phalaropes (*Phalaropus* spp.), kittiwakes (*Rissa* spp.), shearwaters (*Puffinus* spp.), and others that congregate in the area in significant numbers. For instance, nearly 80% of the global population of Red-legged Kittiwakes (*Rissa brevirostris*) breeds on St. George Island alone, contributing to the globally significant "Important Bird Area" status recognized on the island. Large cetaceans like gray and humpback whales travel thousands of miles from their breeding grounds to feed in the region (Kim and Oliver 1989; Muto et al. 2017). About 50% of the global population of the near-threatened northern fur seals (*Callorhinus ursinus*) breed on the Pribilof Islands during the summer and fall. Their pupping and rearing season produces over 100,000 pups collectively across all Pribilof Islands rookeries each year (Allen and Angliss 2013; Testa 2016). Threatened Steller sea lions (*Eumetopias jubatus*) also haul out on the Pribilof Islands; Walrus Island is the only extant breeding rookery in the Pribilof Islands (Allen and Angliss 2014).

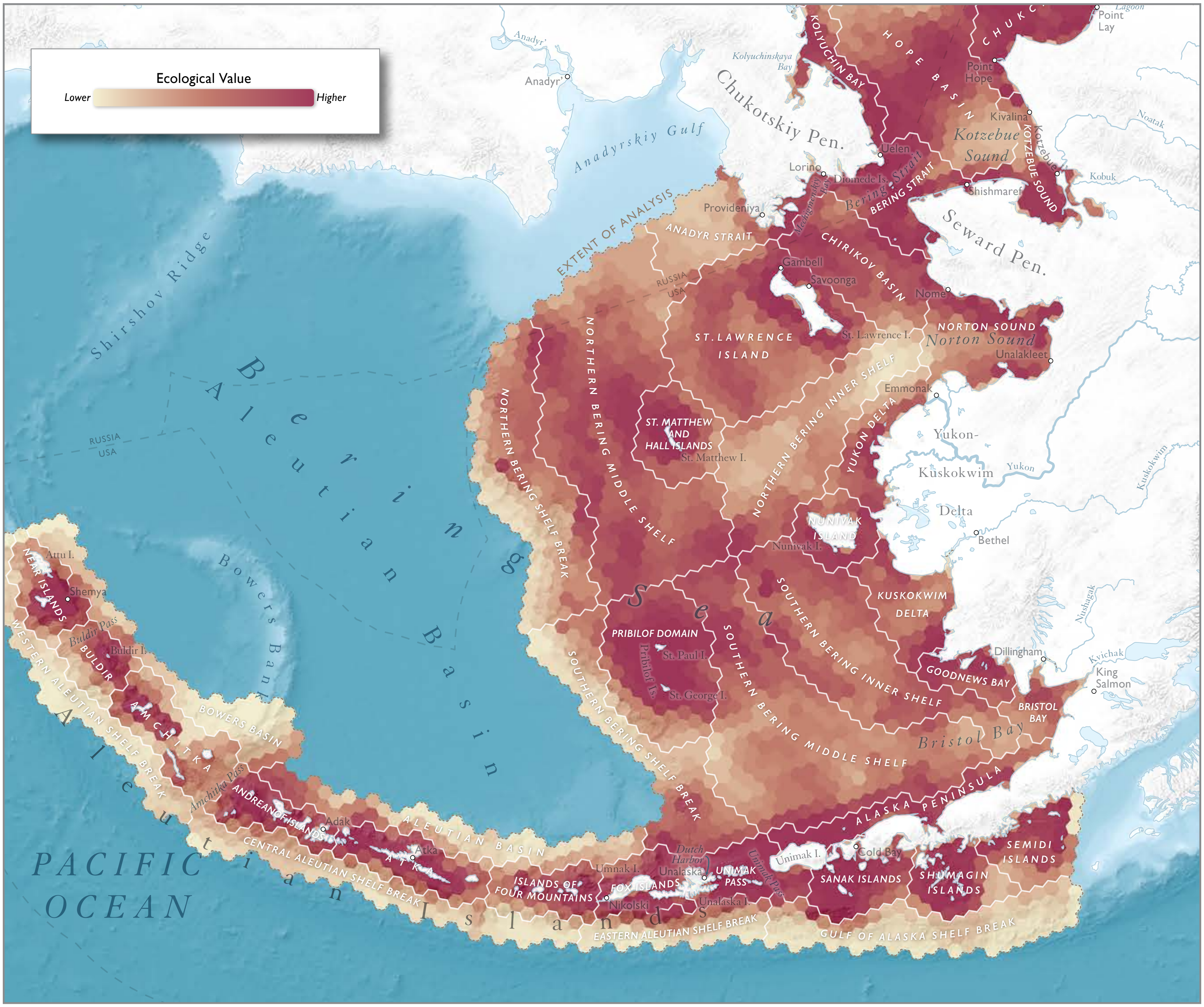
The bounty of diversity and richness found in the area has sustained Alaska Natives throughout the Bering Sea region for millennia. Prehistoric culture across the Aleutian Chain was based almost entirely on marine resources, including hunting marine mammals found around the island chain, fishing the offshore and coastal waters, foraging for fish and shellfish on the rocky reefs, and hunting birds on land and at sea. The wealth of resources supported dense human populations expressing a rich, strong culture. Virtually every archaeologist and ethnographer of Unangan have described what was hunted and how people used mammals, birds, fish, and shellfish (Corbett 2016). The prehistoric inhabitants of the Pribilof Islands created the world's most specialized and successful maritime hunter-gatherer traditions, lasting from roughly 4000 BP to the time of Russian contact in 1741 (Dall 1877, 1878; Hrdlička 1945; Jochelson 1925; Lantis 1970; Lantis and Damas 1984; Laughlin 1980; McCartney 1984; Veniaminov and Black 1984).

Since permanent inhabitation of the islands in the 18th century, this bounty has also provided food security, materials, and deep and enduring cultural connections for the Indigenous residents of St. Paul and St. George (Veltre and Veltre 1981). Today the Indigenous Peoples collectively sharing the time honored bond of living together on St. George or St. Paul prefer to be called Unangax̂ (singular), Unangan or Unangas (plural collective) (Corbett 2016). In recent years, a combination of factors including decreased sea ice extent and density, as well as changing seawater temperatures, have had substantial impacts on the timing and intensity of the spring productivity bloom, resulting in diminished primary and secondary productivity, recruitment, and fecundity of animal populations (Leu et al. 2015; Pollom et al. 2018).

The ecosystem components and geography of the Pribilof Islands have proven valuable to industry as well. Since being described to western science by Georg Wilhelm Steller in 1742, Russian, Japanese, and later American companies and governments harvested northern fur seals commercially, with serious consequences to the population numbers of the species (Bonner 1978; Lander 1981; Steller 1899). More recently, commercial interests have intensely focused on harvesting fish and crab species. The Alaskan walleye pollock fishery is the largest fishery by weight on the planet, and among the highest density of walleye pollock removals are found in the Pribilof Islands region (North Pacific Fishery Management Council 2015). Additionally, commercial operators target Pacific halibut, Pacific cod (*Gadus macrocephalus*), Atka mackerel (*Pleurogrammus monopterygius*), snow crab, and red king crab. Historical overfishing of crabs, especially the Pribilof Islands blue king crab (*Paralithodes platypus*), has resulted in an overfished population declaration in the late 1990s. In

1995, fishery managers implemented a habitat conservation zone (HCZ) prohibiting blue king crab harvest by commercial fisheries (North Pacific Fishery Management Council 2014). The species has nonetheless failed to recover from overfishing, possibly because subsequent elimination of the commercial fishery for red king crabs in the HCZ may have maintained relatively high populations of red king crab juveniles that prey on juvenile blue king crab (Lyons et al. 2016). Current levels of fishing vessel density in the Pribilof Islands region are among the highest anywhere in the Bering, Chukchi, and Beaufort Seas. Not surprisingly, high levels of commercial fishing that occur in the Pribilof Islands region and the especially high densities of piscivorous species of pinnipeds, seabirds, and fish are likely competing for resources.

The *Marine Ecological Atlas of the Pribilof Islands* will serve to explore the ecological importance recognized in the region at a smaller scale to illustrate the distribution and relative abundance of many species by combining local and indigenous knowledge with spatial data obtained from a variety of sources.



There are numerous ecosystem-level hot spots, or areas of high ecological value, throughout the Bering Sea and Aleutian Islands.

Methods

Traditional Knowledge Gathering and Interviews on St. George Island and St. Paul Island

By Lauren Divine

A co-production approach was used to identify the species and processes on which the communities heavily rely or impact and those that are otherwise especially important to the Pribilof communities. A list was developed by the Aleut Community of St. Paul Island Ecosystem Conservation Office (ECO), in conjunction with the City of St. George and the St. George Traditional Council. The list was refined on each island by residents and subsistence harvesters and submitted to Audubon Alaska. Audubon then provided feedback on what species and ecological processes would and would not be able to be mapped as part of the project. Audubon and the ECO then worked together to gather and document the available western science and traditional knowledge regarding these species.

The ECO conducted targeted interviews of past or current subsistence harvesters, hunters, and gatherers, including Elders, to provide insight into the ecological and cultural resources of the Pribilof Islands marine ecosystem, including the human uses of the region. All participants provided free, prior and informed consent; signed participatory waivers and media releases; and were provided a summary of the project, goals, and deliverables. Participants were free to ask questions related to any aspect of the project and were free to conclude the interview at any time.

We sought to foster conversations around the shared values that connect Unangan people to places and nature. Through grounding in local values and discourses, we sought to foster more inclusive, informed and ongoing dialogue with residents in St. George and St. Paul. These stakeholders often feel uncomfortable participating in traditional public meetings and consultations and experience lingering 'research fatigue' from frequent contact with a variety of media reporters and ethnographic researchers. Thus interviews were completely voluntary, with the interview subjects free to answer as many or as few questions as they wished, and provide as much or as little detail to the questions as they wished. Interviews lasted from one to three hours. Participants were provided maps, a copy of the Audubon *Ecological Atlas of the Bering, Chukchi and Beaufort Seas* (2017), and the aforementioned list of priority species at the start of the interview. All interviews were audio recorded. Once interviews concluded, audio files were labeled accordingly and backed up in a minimum of two locations. Any handwritten notes and maps containing hand drawn information were digitized and stored accordingly.

L. Rodriguez

Serafima Edelen teaches youth how to cut *laaqudax̂* to prepare several dishes during a summer culture camp on St. Paul Island.

Audio files were transcribed verbatim. We did not code audio files because, as previous literature suggests, these analyses are implemented on the basis of an arithmetic utilitarian aggregation mechanism, which means it could be subjected to some of the same critiques as monetary cost-benefit analysis approaches, namely that value plurality is restricted and that the aggregation mechanism is arbitrary (Kenter et al. 2016a, b). Thus, we did not aggregate responses and attempt to assign meaning by grouping and converting into quantitative data but rather deliberated on various components of interviews and collectively assessed unique perspectives or insights, individuals' interests and concerns, and overarching themes common across interviews. Individual quotes and information that lent itself to spatial data interpretation was identified and pulled from each interview. These reflections were reviewed with each interviewee before incorporation into the final set of maps and participants were free to edit, remove, add or alter information as they felt appropriate.

All audio files are archived in the ECO and a copy of the interviews for St. George Island participants, including both audio and transcribed word document files, were provided on an external hard drive to the Traditional Council of St. George Island for archival there.

Western Science Data Gathering

By Max Goldman

Survey Effort Layer for 150nm Bird Maps

To generate the indicator of survey effort, North Pacific Pelagic Seabird Database (NPPSD) observation points were aggregated into 5km cells, with each cell counting the number of unique surveys made in that area. Each survey was identified by its month and year; a small number of points had neither listed.

To this was added the data from Labunski; two surveys were done (2013 & 2014). So, 0, 1, or 2 was added to each 5km cell based on how many surveys were done in that location in addition to the ones in the NPPSD data.

In order to produce a less noisy, more easily-interpreted surface, this survey effort dataset was then smoothed. All no-data areas were replaced with 0 (since there was no survey done there) and upsampled to 1.5km cells. The dataset was then smoothed by running focal statistics with a 10x10 cell window, using the mean operator. The resulting raster was broken into two classes: 0–2 surveys, and >2 surveys.

Islands Resizing

For 150nm maps

Otter Island has been scaled up 300% (i.e. it has 3x the linear dimensions and 9x the area). Walrus Island has been scaled up 500%.

30nm maps

Otter Island is at scale.

Walrus Island is scaled up 167%.

150nm Bird Maps Kernel Density Parameters

40km search radius, 200m cell size, geodesic distance calculation.

30nm Bird Maps Kernel Density Parameters

15km search radius, 70m cell size, geodesic distance calculation.

5nm Bird Maps

10km search radius, 10m cell size, geodesic distance calculation.

These output rasters were then masked. The mask was a 5nm buffer around each island, minus the island itself.

150nm Bird Map Colony Numbers

All rounded to two significant figures to avoid a false sense of precision.

Project Coordinate System, for 30nm and 150nm Maps

Lambert Azimuthal Equal Area

56.9, -169.9

St George 5nm Coordinate System

Lambert Azimuthal Equal Area

56.57, -169.63

St Paul 5nm Coordinate System

Lambert Azimuthal Equal Area

57.18, -170.26

Fishes & Lower Trophic

Data Preparation for: Benthos/Epibenthos, Zooplankton, Red King Crab, Snow Crab, Blue King Crab, Pacific Cod, Pacific Halibut, Walleye Pollock, and Pacific Salmon.

Trawl Survey data were from National Marine Fisheries Service Resource Assessment and Conservation Engineering (NMFS RACE) and the Eastern Bering Sea Continental Slope Survey. For the NMFS RACE data, all points marked as from the EBS (eastern Bering Sea) region were used. Much of the Slope Survey data duplicated the NMFS data; duplicate points were removed via a search for unique combination of Vessel/Cruise/Haul.

Since each species found in a haul received its own point, the dataset was constrained to only include the ~14,400 unique sampling location (via vessel/cruise/haul). If a species was reported at some locations, but not others, it was assumed to have a Weight of Catch per Unit Effort (WTCPUE) of 0 by default unless another value was reported.

After this, the data were aggregated spatially. For the NMFS RACE data, most of the samples were in clusters, centered on individual sampling stations that were identified in the attribute table. For the species of interest, the mean WTCPUE was calculated at each sampling station (including the 0 values), as well as the mean lat/lon associated with that sampling station. The Slope Survey data did not identify sampling stations, and so were not aggregated.

Surfaces were then generated from this point shapefile via Empirical Bayesian Kriging (EBK) with the following parameters: K-BESSEL semivariogram, with a 1.5 overlap factor, 50km radius, 64 maximum neighbors and 25 minimum neighbors. All other parameters were left at the default setting.

EBK rasters were generated with a cell size of 1km against the project's coordinate system. They were then upsampled to 200m (cubic convolution) and clipped to a mask that constrained them to both the 150nm boundary around the Pribilof Islands and to areas above the 1200m isobath. This isobath was generated from Alaska Region Digital Elevation

Model (ARDEM) data and smoothed slightly. The upsampling before clipping was to reduce obvious pixelation. After clipping, the data were classified in quantiles. Upon exporting to Photoshop and placing in the basemap template, the data were de-noised via a 10px Median filter.

Commercial Fishing

Using the AK Groundfish Observer Database data as a starting point, a TARGET field was added to each row to indicate if it represented a commercial target (= 1) or bycatch (= 0).

Targets are defined by combination of the species and gear fields, as follows (LGL = longline; POT = pot gear):.

- Pacific Cod: POT or LGL
- Sablefish (Blackcod): POT or LGL
- Pollock: All gear types
- Pacific Halibut: LGL
- Red King Crab: POT
- Opilio Tanner Crab: POT
- Tanner Crab Unidentified: POT
- Tanneri Tanner: POT

NOAA maintains this table converting their species names to scientific names: https://www.afsc.noaa.gov/FMA/species_lookup.htm. Summary statistics were calculated in ArcMap in order to distill the data down into a new shapefile, which listed the Target, Bycatch, and Total (all in metric tons) for each location, summed across all years, before kernel density analysis.

Kernel density parameters: 40km search radius, 200m px, geodesic. Same as 150nm bird maps. These were then clipped to the same extent as the fishes/lower trophic maps: areas above the 1200m isobath that were also 150nm from the islands.

5nm Basemaps

Coastline and water polygons from OpenStreetMap. These data are free to use, but attribution is required:

- © OpenStreetMap, www.openstreetmap.org

ArcticDEM was used for the land relief on these maps. Due to some artifacts, the data required manual curation around the edges of the islands (including patching with coarser 3DEP data in Photoshop). Acknowledgement line for these data:

- DEMs provided by the Polar Geospatial Center under NSF-OPP awards 1043681, 1559691, and 1542736.

Land cover data are National Land Cover Database (NLCD) 2011. Ocean relief is from Zimmerman and Prescott 2018.

30nm Basemap

Ocean relief from Zimmerman and Prescott 2018.
Land relief from ArcticDEM Landcover NLCD 2011.

150nm Basemap

Ocean relief from Zimmerman and Prescott 2018 (NOAA), patched with ARDEM data where needed. Land relief from ArcticDEM Landcover NLCD 2011.

Fishing Vessel Density

Raster was upsampled to 200m pixels to be clipped to the 150nm extent. Exported a simple linear ramp.

Overall Vessel Density

Took raster provided, clipped to map extent, then exported the sqrt of that raster. Blurred in Photoshop.

Vessel density isolines were smoothed out in Illustrator. After making them into polygons, a 2pt corner rounding was applied, then a 95% smooth, then repeated once more. Then tiny round polygons/holes were manually cleared.

Steller Sea Lion

Haulout and rookery points from Fritz et al. 2015 and interpreted from Kenyon 1962. In instances where the Kenyon 1962 and the Fritz et al. 2015 points are likely referring to the same location, but are not quite aligned, Fritz et al. 2015 was used. One location was excluded data based on feedback from the Traditional Knowledge data workshop.

Northern Fur Seal

Rookery data were digitized from Zeppelin and Ream 2006. Data from NOAA Marine Mammal Laboratory 2015 were too coarse to use at this scale, though they were used as reference 2015. As with SSL, the use of Zeppelin and Ream 2006 is prioritized below the use of Traditional Knowledge data, and will be added only where Traditional Knowledge data does not already show a rookery. There is also a segment that is to be excluded, according to the results of the Traditional Knowledge data workshop, as denoted in metadata.

Traditional Knowledge Data

Data resulting from the Traditional Knowledge data collection and Traditional Knowledge data workshops were categorized into it to a set of activities — nesting, egging, presence, etc. Each point/line/polygon was either digitized from a hand-drawn map, or based on a text description.

Each feature has the following fields:

- SPECIES: the species (or group of species, in some cases) to which the feature applies
- DESCRIPT: a description of the activity associated with this feature
- TIME: whether this is a contemporary or historical activity
- DETAIL: an optional additional piece of information about the activity
- NOTES: a pointer back to the source of the feature. If drawn from specific workshop comments, numbered on maps and in Word documents, those numbers are given. If drawn from workshop data

without note, *Workshop General* is given. *Pre-Workshop* indicates data from interviews during the Traditional Knowledge data collection efforts, prior to the workshops. Finally, *Implied* indicates that this feature was implied by others (see below).

Once all the data had been digitized, they were cleaned to remove overlaps between features. A participant drawing on one map might mark a nesting location, while a person drawing on another map might mark a similar nesting location that partially overlaps the first. All features with the same value across all four data fields were unified into single features. If a feature was marked as simply having "presence" of a species, and was later overlapped by a more detailed description (e.g., nesting, haulout), the portion of the feature with "presence" was deleted in favor of the more detailed description. Likewise, if there was an overlap between a contemporary and historical version of the same species/description, the historical version was deleted. Features in the database repeat as needed, to describe multiple species/activities in the same location.

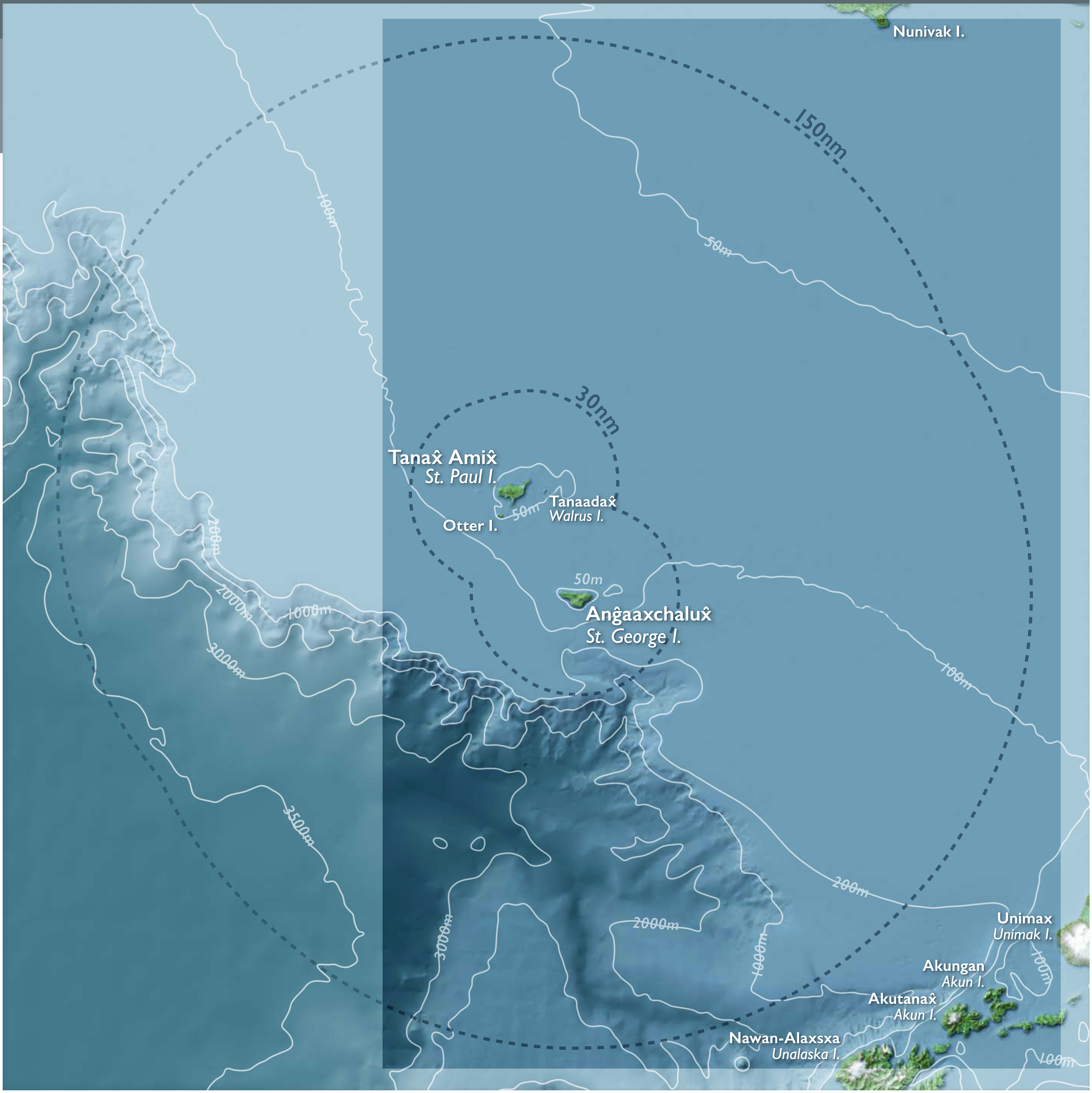
Subsistence data were used to imply ecological information. If subsistence features indicated "egging" happening in a certain location, "nesting" was assumed to occur there if it had not already been explicitly marked as "nesting." Likewise—for mammals only—hunting/harvesting was assumed to imply "presence." Due to the possibility of hunting on the wing, hunting was not assumed to imply presence for birds.

H. McFarland

Stored crab pots are a familiar sight near the town of St. Paul.

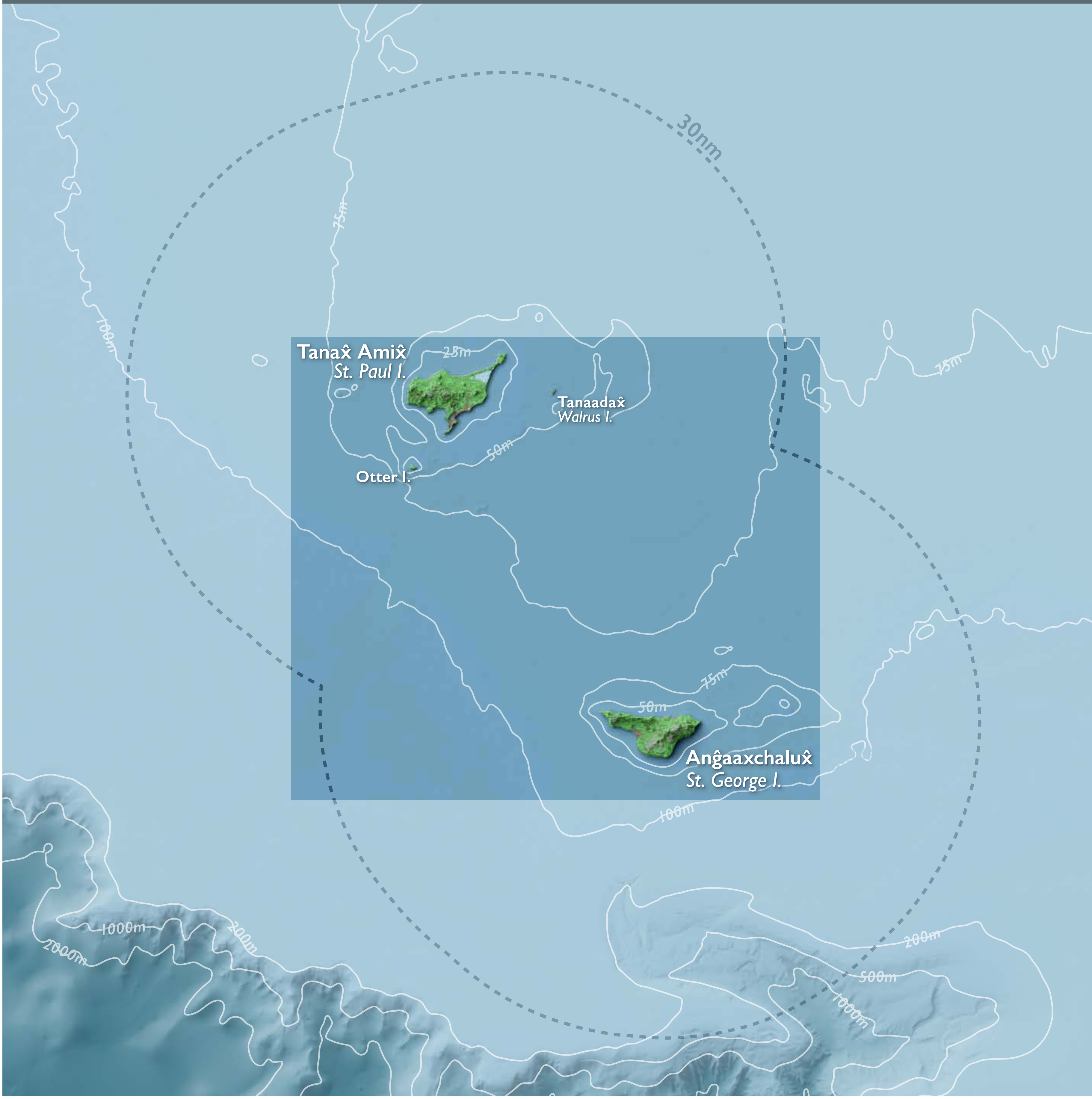
150NM

Pribilofs Overview



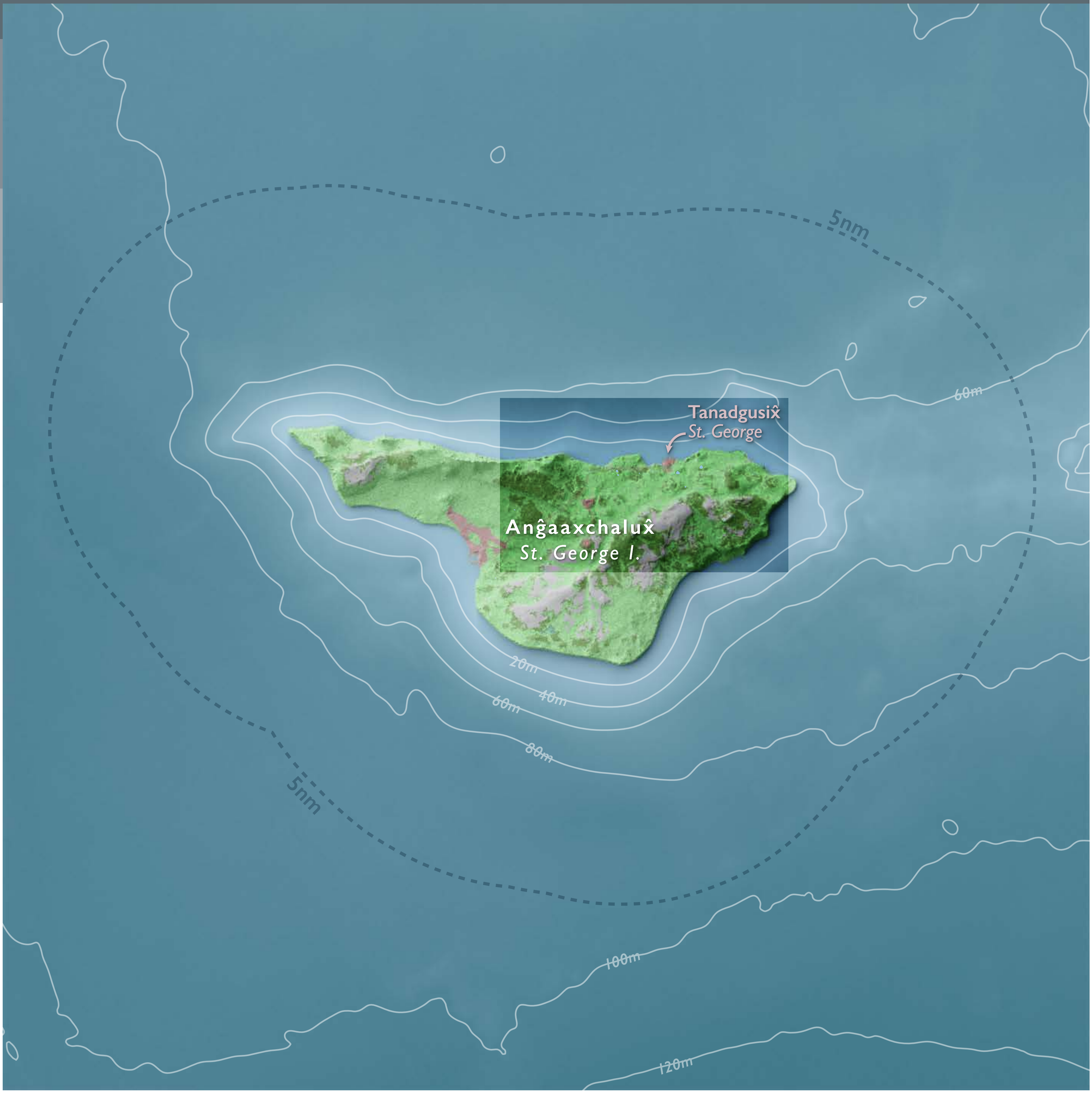
30NM

Pribilofs Overview



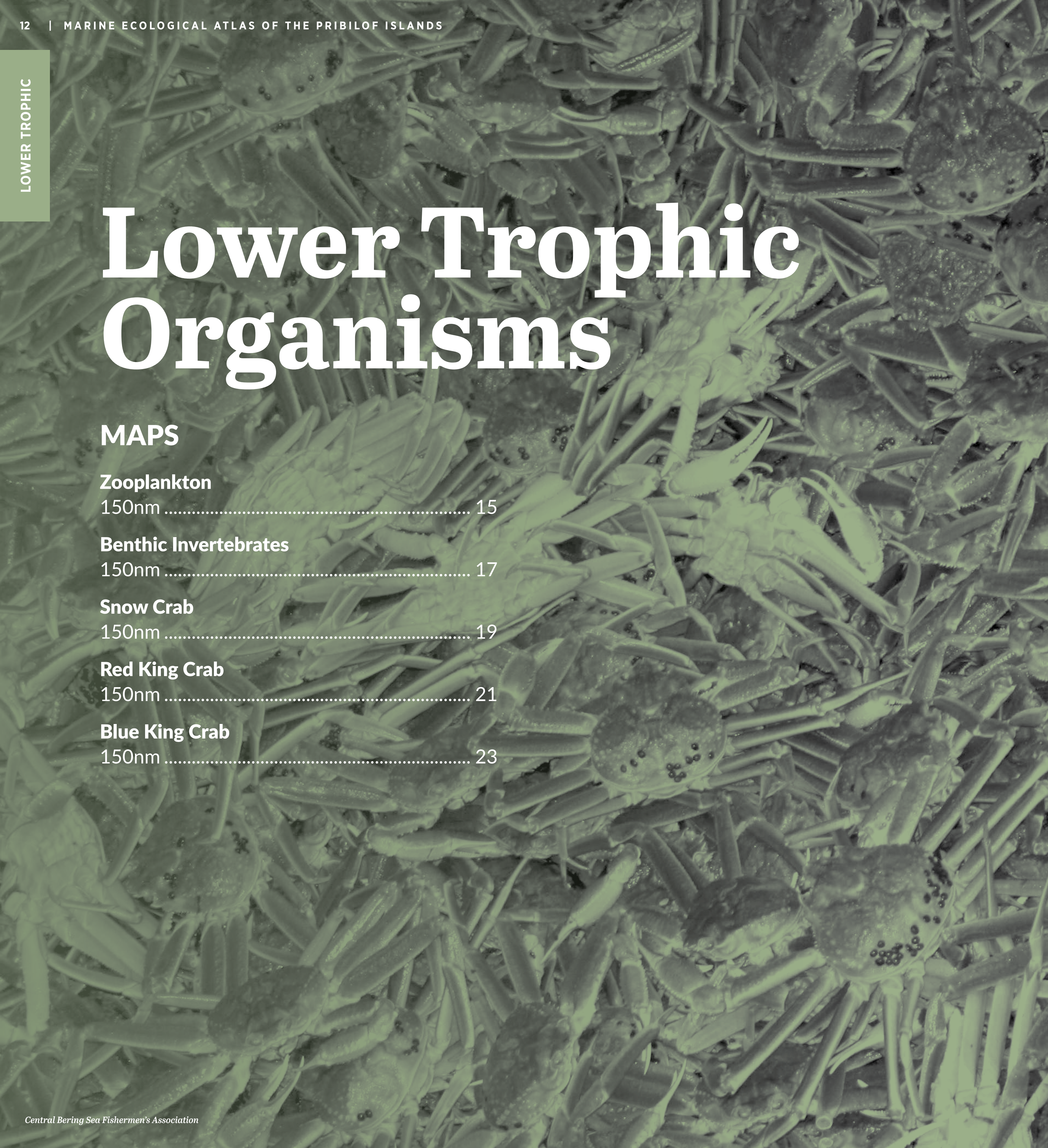
ST. GEORGE 5NM

St. George Overview



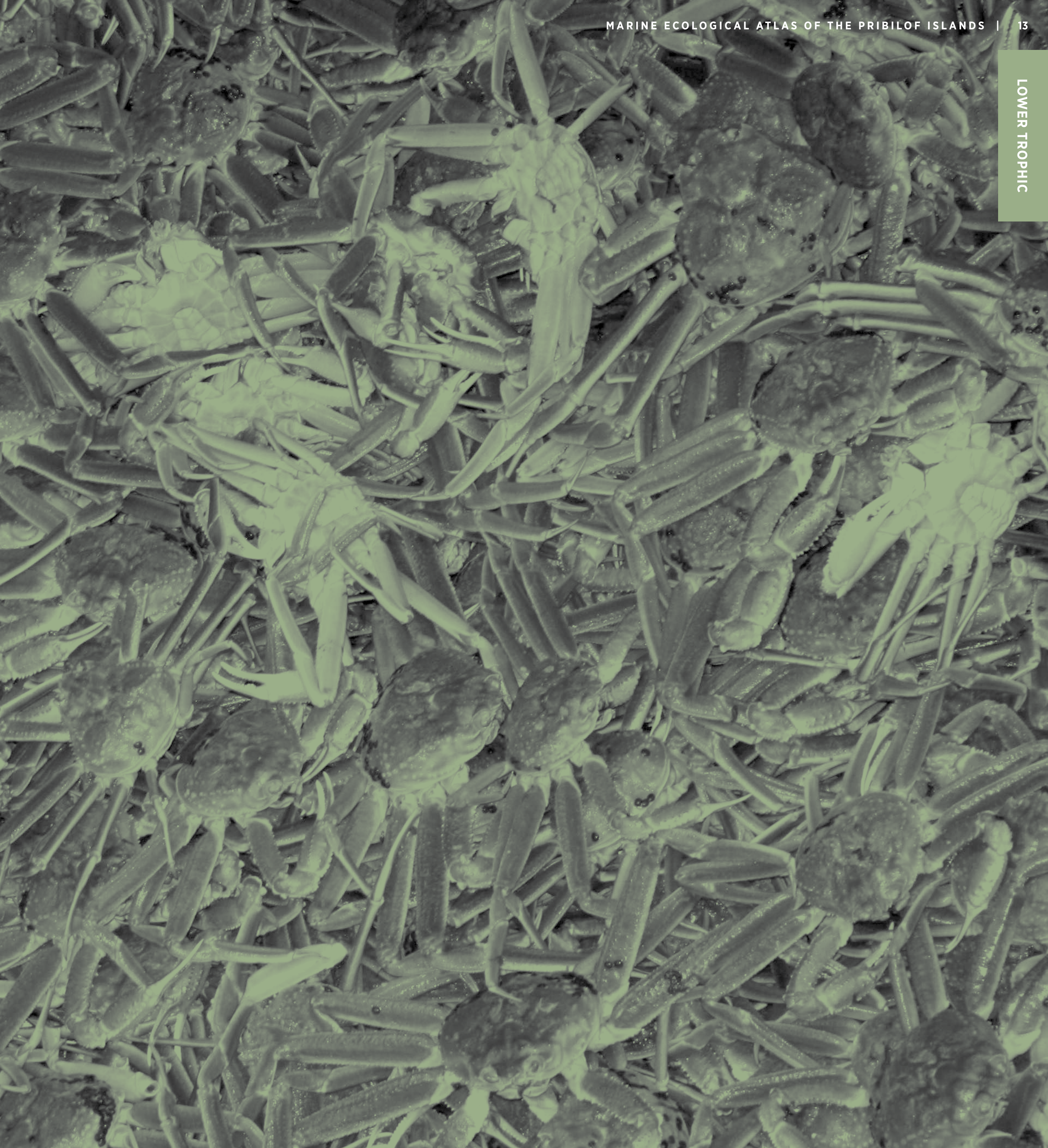
ST. PAUL 5NM

St. Paul Overview



Lower Trophic Organisms

MAPS

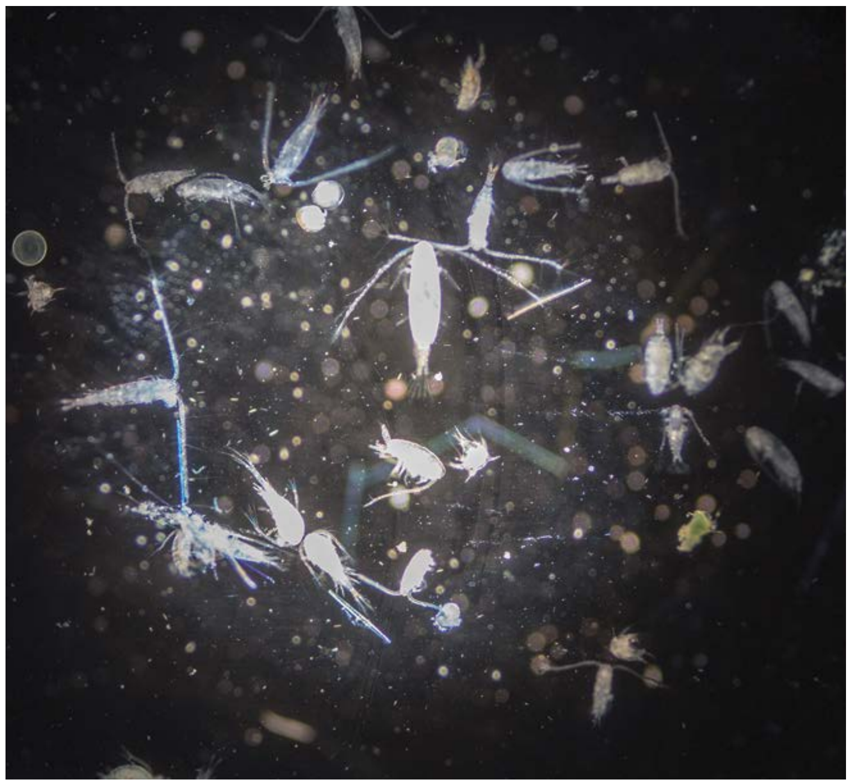


Zooplankton

Zooplankton are tiny animals living and swimming in the water column that link phytoplankton (primary producers) to most other animals in marine ecosystems. Zooplankton include a diverse assemblage of larval fishes and crabs (collectively called ichthyoplankton), pelagic snails (pteropods), arrow worms, krill (euphausiids), and other small crustaceans such as bottom-dwelling amphipods. Zooplankton are abundant, widely distributed, and encompass thousands of species across multiple phyla. Two crustacean zooplankton groups are of particular importance in the eastern Bering Sea (EBS): krill or euphausiids, and copepods (Hopcroft et al. 2008). Many species of copepods and krill store large amounts of lipids or fats, and therefore supply their predators with an energy-rich food source (Davis et al. 1998). Zooplankton bridge the trophic gap between primary producers and larger predators, and represent nearly every taxonomic group of fish and invertebrates during part, if not all, of their life cycle (Sigler et al. 2016). They repackage solar energy fixed into sugars by phytoplankton and provide a prey base that is diverse in size and nutritional quality to larger predators (Hunt et al. 2002a). For example, walleye pollock, a commercially important groundfish predator that occurs in the EBS, benefits from diets with energy-rich zooplankton (Moss et al. 2016; Siddon et al. 2014).

> "I understand to some degree what the economic benefits of these waters are. We are really blessed as people to have these rich ecosystems near us that provide the kind of wealth and seafood and nutrients for marine mammals and things like that."
>
> ~ P. Pletnikoff

Zooplankton are an important food source for many of the subsistence animal species on the Pribilof Islands, whether they are consumed directly by subsistence species (e.g., auklets, crabs), or indirectly via providing the prey base for higher trophic level feeders (e.g., marine mammals). Zooplankton distribution changes over time and is strongly influenced by ocean conditions such as wind and currents, ice coverage, and phytoplankton bloom dynamics (Coyle et al. 2008; Hunt et al. 2002b; Ohashi et al. 2013; Sigler et al. 2016). Late sea-ice retreats, caused by a colder winter and spring, lead to early spring phytoplankton blooms; whereas early ice retreats, caused by a warmer winter and spring, lead to later open-water blooms (Hunt et al. 2002b; Sigler et al. 2016). Warmer waters and earlier sea-ice retreats tend to favor the production of jellyfish and small, less nutritious copepods like *Pseudocalanus* spp.; colder waters favor larger, more energy dense zooplankton such as *Calanus* spp. copepods (*C. marshallae* and *C. glacialis*), and larger populations of krill (Coyle et al. 2008; Eisner et al. 2014; Ohashi et al. 2013).

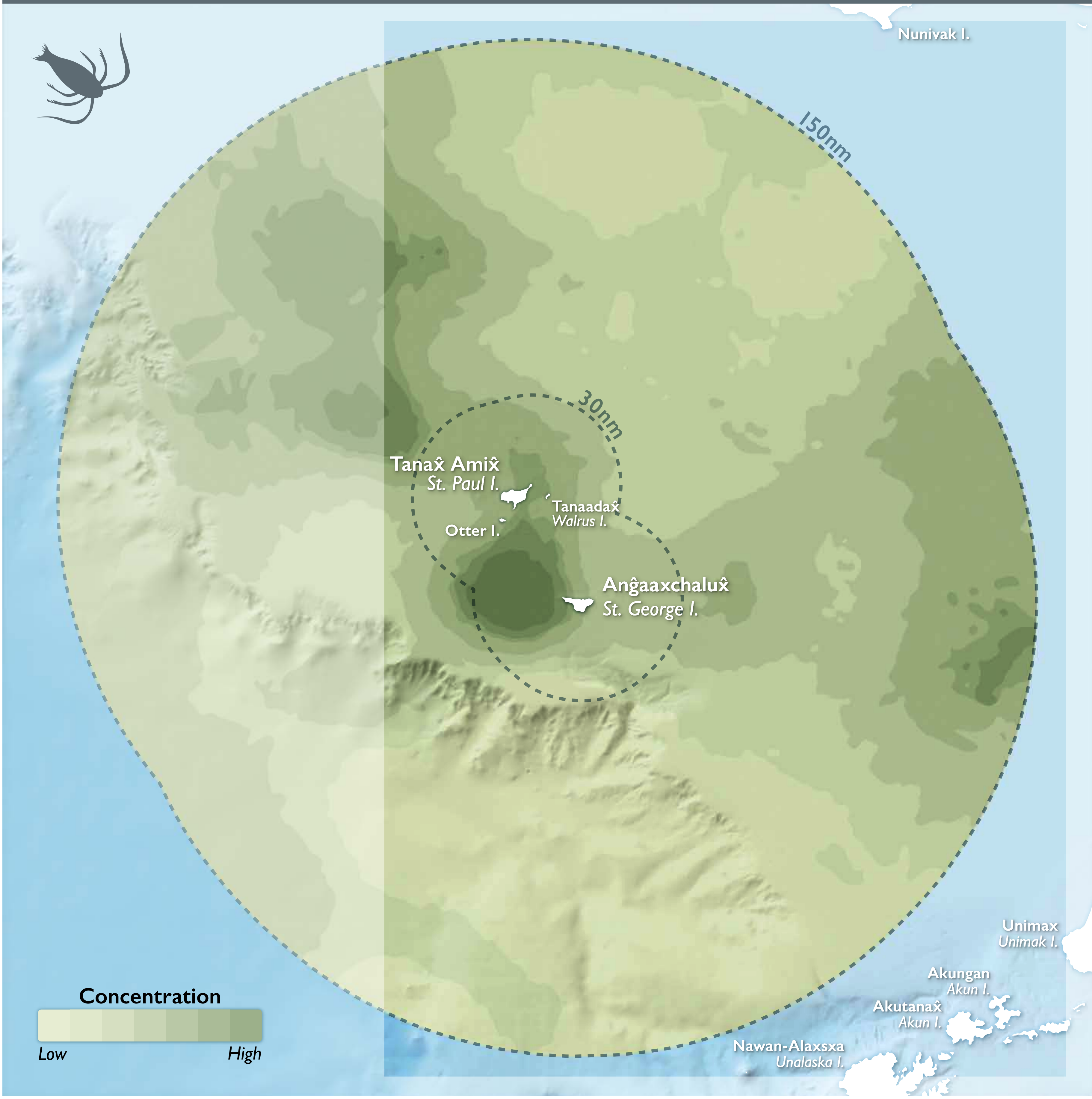


Adobe Stock

Calanus spp. contain rich sources of lipids and other nutrients that support a diverse food web in the Bering Sea.

150NM

Zooplankton



Benthic Invertebrates

Benthic invertebrates are animals that lack a backbone which live on or in the seafloor. Some benthic invertebrates form structures that become habitats (e.g., sponges and corals), others live in the substrate (e.g., burrowing worms), and some are mobile and travel on the surface of the seafloor (e.g., crabs). Benthic invertebrates comprise a large proportion of the total marine biomass and species diversity in the Bering Sea. Their aggregate role in the ecosystem is an important transfer of energy from lower to upper trophic levels (Coyle et al. 2007).

The benthic community in the eastern Bering Sea is dominated by purple-orange sea stars (*Asterias amurensis*), basket stars (*Gorgonocephalus eucnemis*), and sponges. Crabs are also important benthic invertebrates and red king, blue king, and snow crab are summarized separately in this Atlas.

Benthic organisms rely on high primary production from the water column and are less affected by seasonal and annual variability in productivity than pelagic species (Bluhm and Gradinger 2008). Areas of very high primary productivity, such as the Pribilof Islands region, produce more biomass than is consumed by zooplankton (Springer et al. 1989). This excess biomass falls to the seafloor, providing food for a rich benthos (Grebmeier et al. 1988). Benthic invertebrates like corals and sponges provide habitat for many commercially important species (Stone 2014). These include but are not limited to Atka mackerel (Malecha et al. 2005; Stone 2006), red king crab (Pirtle and Stoner 2010), and several rockfishes (Stone and Cairns 2017). Corals, in particular, are long-lived and grow slowly (Andrews et al. 2002), so it takes years before a colony effectively becomes fish habitat (Stone and Cairns 2017). Several canyons occurring adjacent to the Pribilof Islands, including Zemchug to the northwest and Pribilof to the southeast, represent important productive areas that have significant concentrations of deep sea corals. In fact, the Pribilof Canyon represents the most significant location for habitat-forming deep sea corals and sponges along the entire eastern Bering Sea shelf.

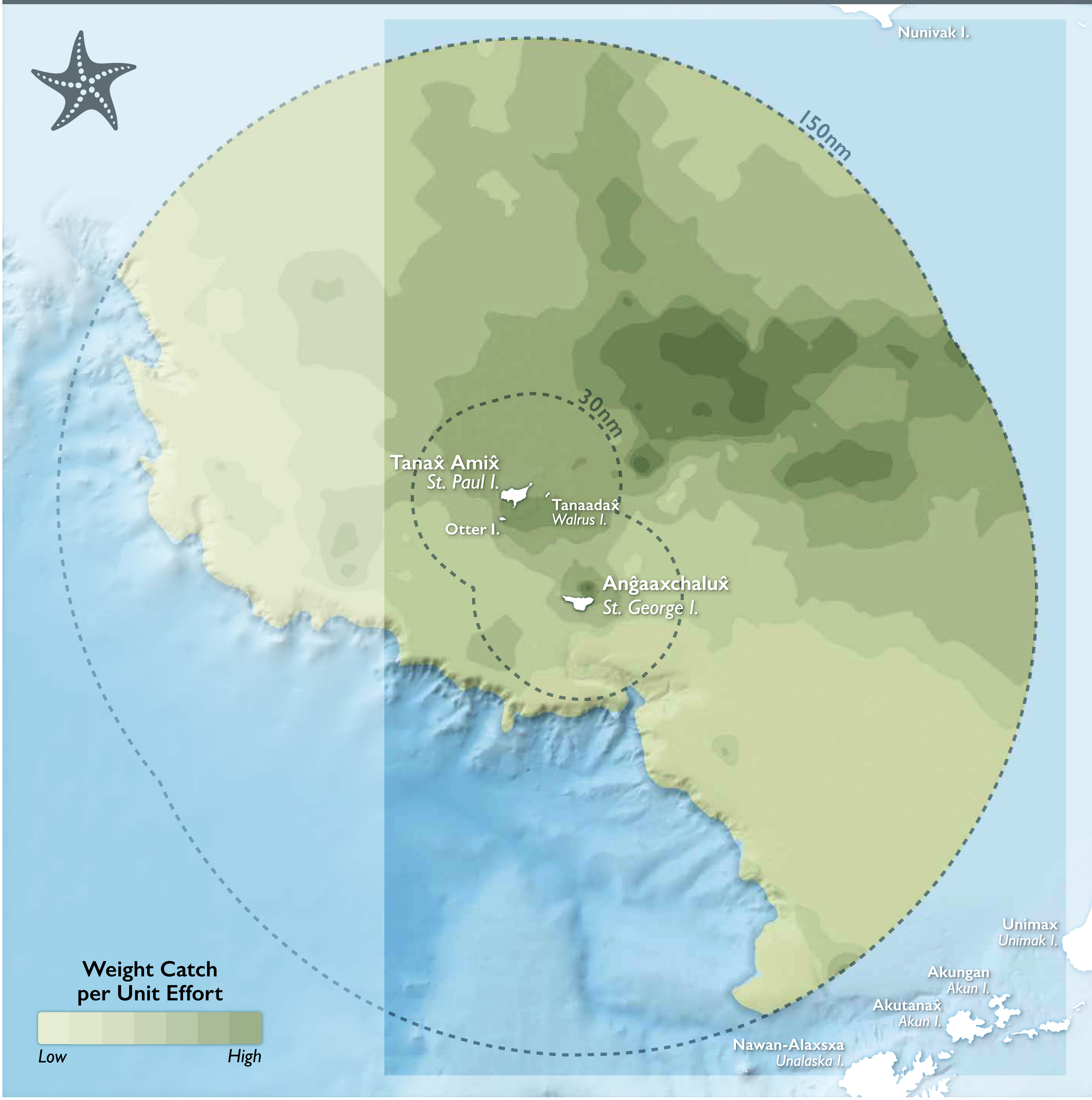
Various commercial fishing gears, particularly bottom trawling, can have long-term impacts on benthic habitat (Heifetz 2002; Rooper et al. 2016; Stone and Cairns 2017; Witherell and Coon 2002). When corals are damaged by fishing gear, they can take decades to recover, and repeated fishing disturbances in an area can slow growth rates further (Stone and Cairns 2017). It is important to consider the time necessary for slow-growing, long-lived corals and sponges to rebuild or replace damaged structures when assessing habitat degradation and subsequent recovery (Andrews et al. 2002; McConnaughey et al. 2000; Rooper et al. 2011). Additionally, some coral growth is negatively affected by warmer waters (Stone and Cairns 2017) and ocean acidification (Fabry et al. 2009), so as ocean temperatures continue to rise, the effects observed from fishing activities will be exacerbated and increase recovery time.

A. Dietrick / UAF CFOS

The rocky benthos around the Pribilof Islands hosts a wide variety of invertebrate life living on and among the boulders, including six species of sea stars like this mottled sea star, *Evasterias troschelii*.

150NM

Benthic Invertebrates



Snow Crab

Snow crab (*Chionoecetes opilio*), also known as opilio crab, is the most valuable commercial crab species in North Pacific (North Pacific Fishery Management Council 2015) and North Atlantic waters (Hébert et al. 2014). They are well known by American consumers as the animal behind "all-you-can-eat" crab legs at popular seafood restaurants and as "opies" on the Discovery Channel reality series *Deadliest Catch*. Their congener (meaning animals of the same genus, but comprising a different species genetically) the Tanner crab (*C. bairdi*), is a lesser-known, albeit slightly larger crab found in both the eastern Bering Sea (EBS) and the Gulf of Alaska.

Snow crabs are brachyurans, or true crabs, with a body covered in a hard exoskeleton that they must shed, or molt, in order to grow larger (Moriyasu and Mallet 1986). Molting is instrumental in crab survival as it also enables them to repair any damaged or lost limbs. In contrast to other crabs, snow crabs experience a terminal or final molt, after which they stop growing. The typical life span of snow crabs is 7-10 years after settlement to the seafloor (Kon et al. 2010). Adult male snow crabs are larger than females, a pattern known as sexual dimorphism. The body and claw size difference allows for males to grasp and protect smaller females during the mating process. A male will mate with a female for the first time after her terminal molt, which happens in the winter (Ernst et al. 2005). Males fight for the opportunity to mate by grasping a female prior to her molting and protecting her through the molt.

Although snow crabs are not directly associated with sea ice, they are affected by how changes in sea ice impact bottom temperatures. With sea ice coverage contracting, the Bering Sea cold pool (a mass of water less than 35°F or 2°C), is also shrinking and is now limited to the northern Bering Sea (Orensanz et al. 2004). This northward contraction of the cold water preferred by juvenile snow crabs (Dionne et al. 2003) has subsequently led to a northward shift in their distribution, away from the Pribilof Islands (Burgos et al. 2013; Orensanz et al. 2004; Zheng and Kruse 2006).

Snow crabs are benthic forage feeders; they primarily eat polychaete worms and bivalves, but also brittle stars, snails, and other crustaceans (Squires and Dawe 2003). Among the crustaceans they eat, snow crabs have been recorded cannibalizing other snow crabs (Lovrich and Sainte-Marie 1997). Stomach content analyses have shown up to 22% juvenile snow crabs and up to 10% juvenile Tanner crabs in snow crab stomachs (Livingston 1989). Another prominent predator of snow crabs is the Pacific cod (*Gadus macrocephalus*). In fact, predation by Pacific cod on snow crab in the EBS has been hypothesized to influence the strength of recruitment to the fishery (Burgos et al. 2013).

The commercial fishery for snow crabs occurs in the EBS and represents the largest and most valuable crab fishery in the US (North Pacific Fishery Management Council 2010). During the 2017-2018 season, 8,600 metric tons of male snow crabs were caught and retained (North Pacific Fishery Management Council 2018; Bechotol et al. 2018). After peak catches in the 1990s, the snow crab population in the EBS started to decline and the fishery collapsed by 1999, followed by a rebuilding period (Zheng et al. 2002); the stock was declared rebuilt in 2011 (North Pacific Fishery Management Council 2011) and commercial fishing has since resumed in the region.

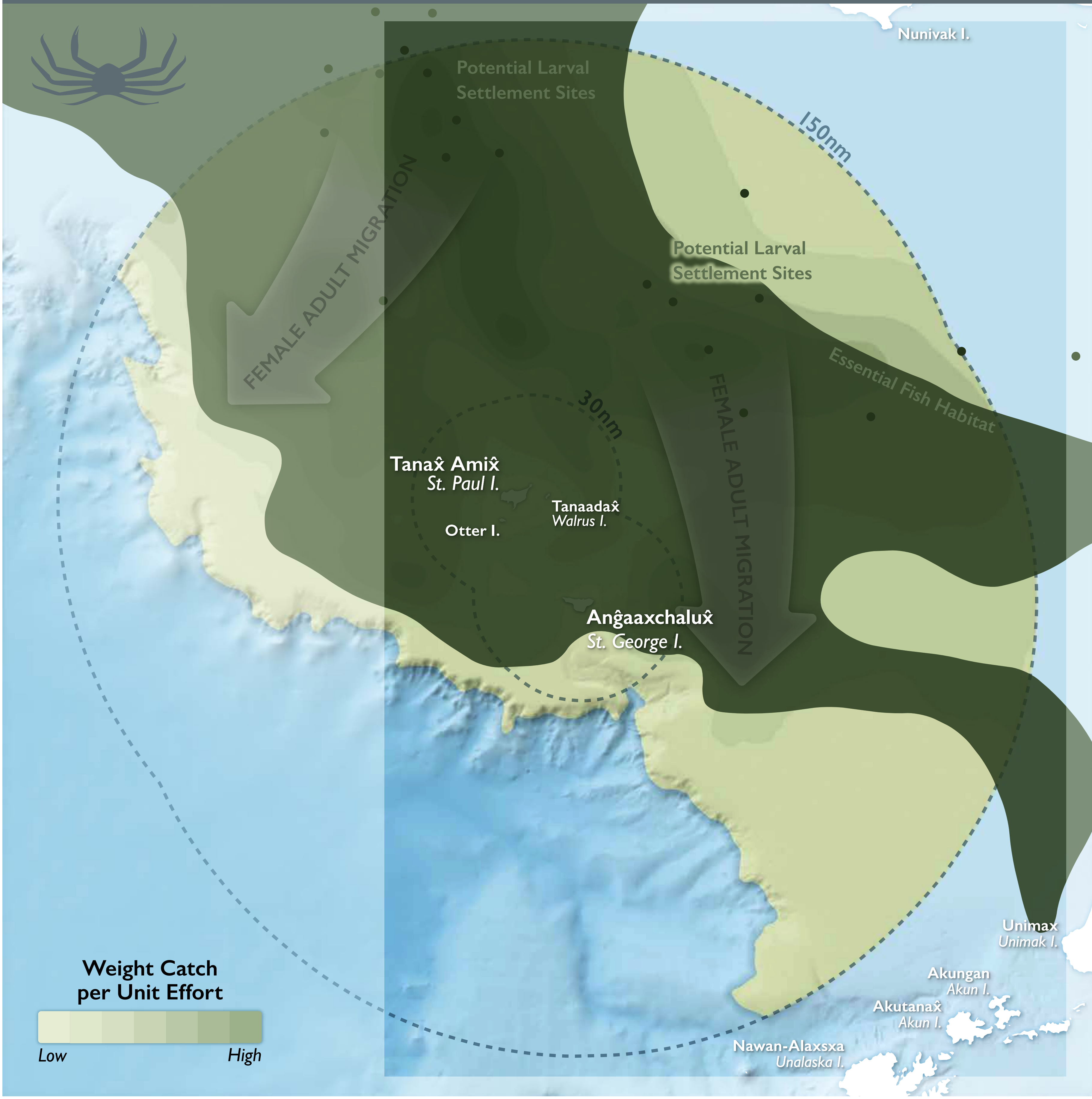
One concern for future snow crab populations is how ocean acidification will affect snow crab productivity. Ocean acidification affects any animal with calcium carbonate shells by dissolving their exoskeletons; this dissolution can affect larval snow crabs by slowing their growth and reducing their calcium content (Long et al. 2013). For many animals, the larval stage of development is their most vulnerable life history stage and less protection could mean lower survival, which would subsequently reduce recruitment to adulthood and the fishery (Punt et al. 2016)

"When they had the opilio season up here when the harbor was functional, we saw right in front of our very eyes that the quota kept going up but the crab were getting smaller. We noticed that and we would go to the processors and look and watch through the window. We watched these critters [snow crab] come through and thought, 'Look at how small they are now. We're not going to have any pretty soon.' That's when they shut down the fisheries here."

~ M. Merculieff Sr.

150NM

Snow Crab



Red King Crab

Red king crabs (*Paralithodes camtschaticus*) are generally distributed throughout the North Pacific from deep shelf waters <820 feet (250 m) to shallow, nearshore, intertidal environments (Stone et al. 1992; Zheng and Kruse 2006). They range from southeast Alaska, along the Aleutian Islands, throughout Bristol Bay and the eastern Bering Sea (EBS), north to Kotzebue Sound, and westward toward Japan and Russia. Red king crabs are the largest crab species found in Alaska waters (North Pacific Fishery Management Council 2016) and are commercially valuable, with a portion of commercial harvest being processed on St. Paul Island annually.

Red king crabs have a hard exoskeleton made out of chitin and grow by molting. Unlike snow and Tanner crabs (*Chionoecetes opilio* and *C. bairdi*, respectively), which have a terminal molt to maturity, king crabs continue molting throughout their lifecycle (McCaughran and Powell 1977). This is one reason red king crabs are relatively large in size compared to other crab species in the same marine ecosystem. Another difference between red king crabs and snow crabs is the number of legs they have, due to differences in their taxonomic classifications. Red king crabs are in the sub-order Anomurans and have six walking legs, while snow crabs are Brachyurans, characterized by eight walking legs.

Podding behavior is unique to red king crabs and involves hundreds to thousands of crabs clustering together in dense aggregations grouped by maturity (juvenile vs. adult) and sex (Dew 1990, 2010). Red king crab pods can cover vast areas of the seafloor (Dew 2010). Unlike other crabs, these pods occur year-round and are not specifically tied to mating or molting behaviors, but rather may offer safety in numbers while resting between daily foraging excursions (Dew 1990, 2010).

"From Rush Point to Dalnoi—that whole area was just plugged with crab boats (from 1978-1985)..."

~ M. Merculieff Sr.

Red king crabs molt to grow, molting numerous times (8–11) in their first year (Westphal et al. 2014). They continue to molt several times per year in the following two to three years post-settlement, after which they molt annually in the spring (Dew 1990). Growth is temperature-dependent, and they grow faster at higher temperatures, attaining larger sizes at similar ages (Stoner et al. 2010). On average, they can grow up to 0.5 inch (11 mm) during their first year, and as the juveniles get larger, their growth increments increase (Westphal et al. 2014).

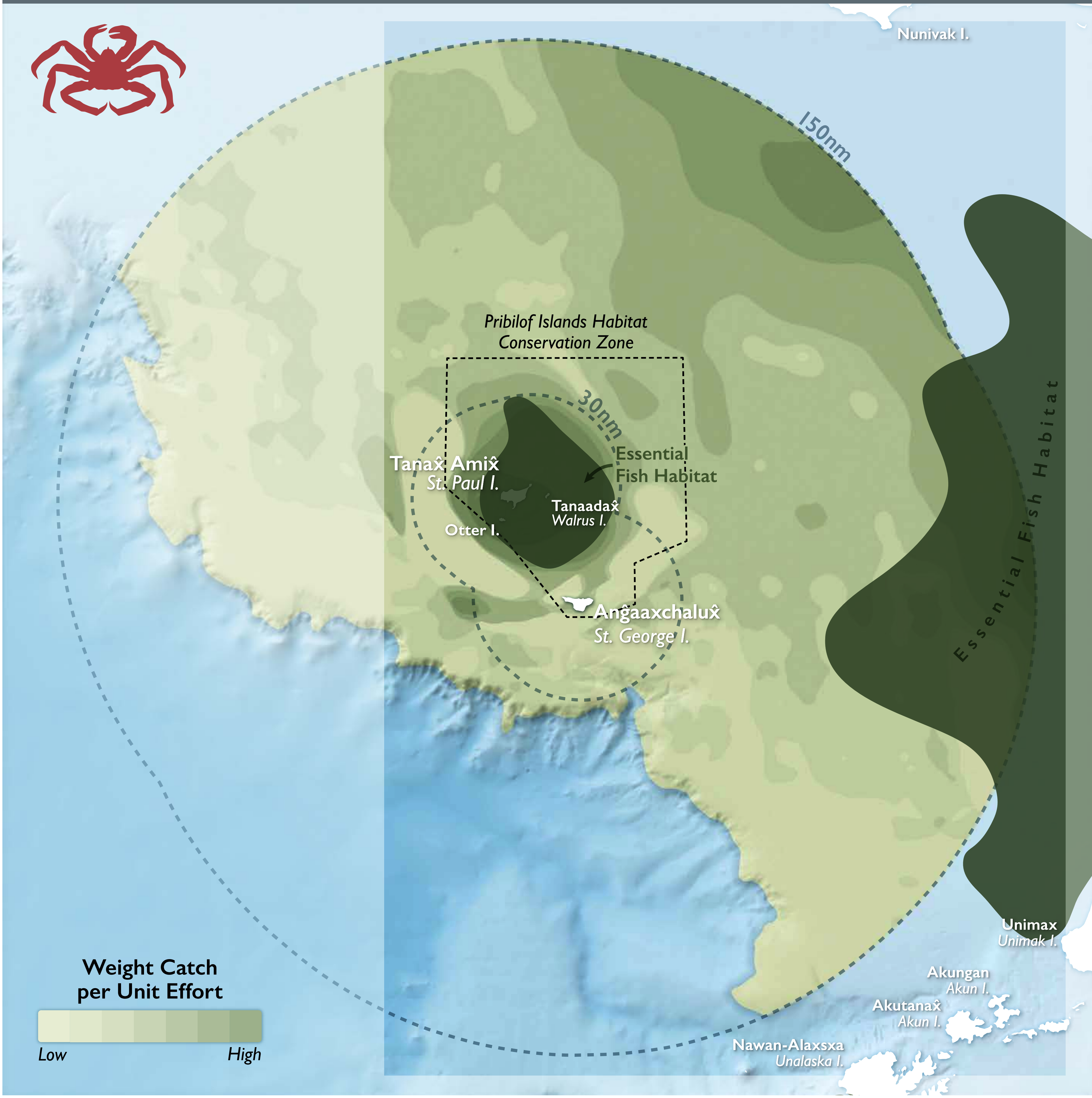
As juveniles, red king crabs forage on algae and the habitat-forming invertebrates they use for their nursery environment (Pirtle and Stoner 2010). Once they grow larger and begin to exhibit podding behavior and seasonal migrations, they eat benthic invertebrates such as bivalves, snails, polychaete worms, sea stars, and anemones, as well as smaller red king crabs (Britayev et al. 2010; Dew 1990; Stoner 2009).

Red king crabs are vulnerable to predation by other crabs and fishes sharing their nursery habitat, including Pacific halibut (*Hippoglossus stenolepis*), northern rock sole (*Lepidopsetta polyxystra*), and kelp greenlings (*Hexagrammos decagrammus*; Dean et al. 2000; Daly et al. 2012; Stoner 2009). Although Pacific cod (*Gadus macrocephalus*) are important predators of snow crabs in the Bering Sea (Burgos et al. 2013), they were found to eat less than 4% of the female red king crab stock during a 1980s study (Livingston 1989) and so may pose little threat to juvenile red king crabs (Stoner 2009).

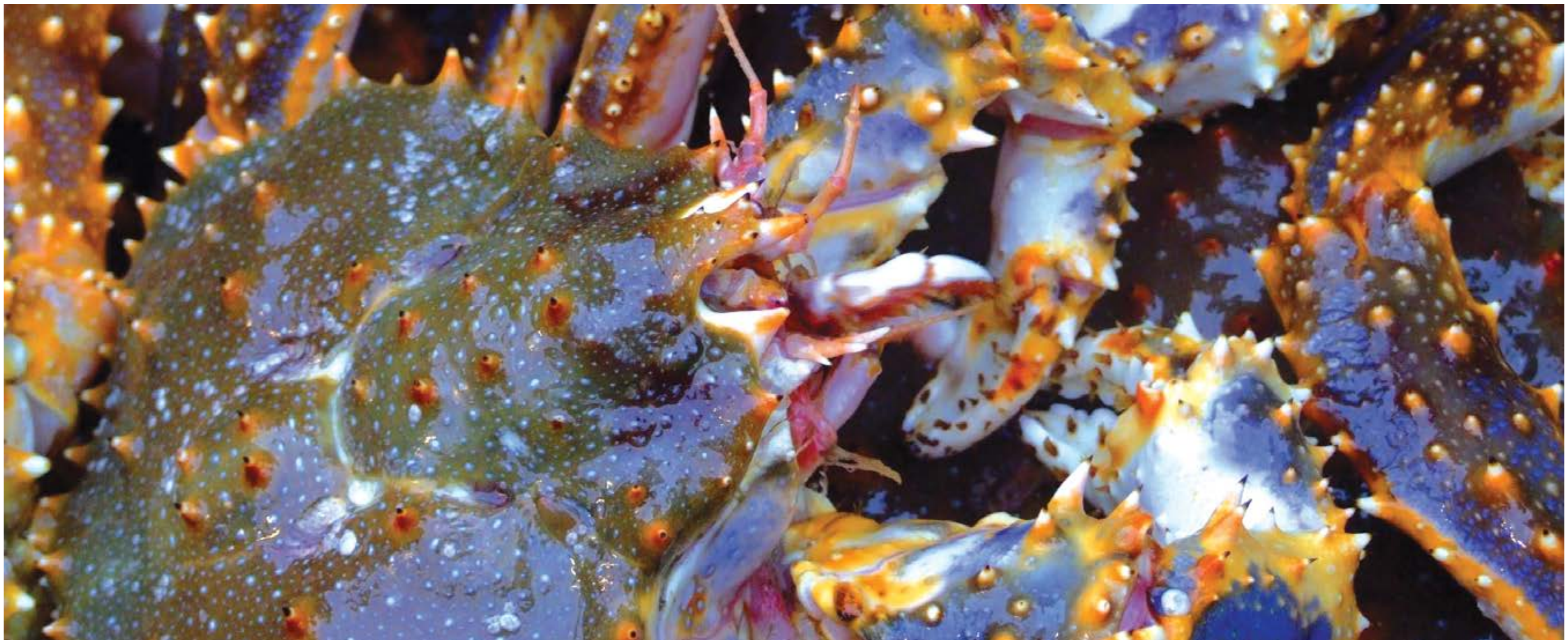
L. Haddock / USFWS

150NM

Red King Crab



Blue King Crab



C. Leroux

The abundance of the Pribilof Island population peaked during the 1980s and mid-1990s, but has been at an exceedingly low level ever since. This population is too low at present to support a directed commercial fishery.

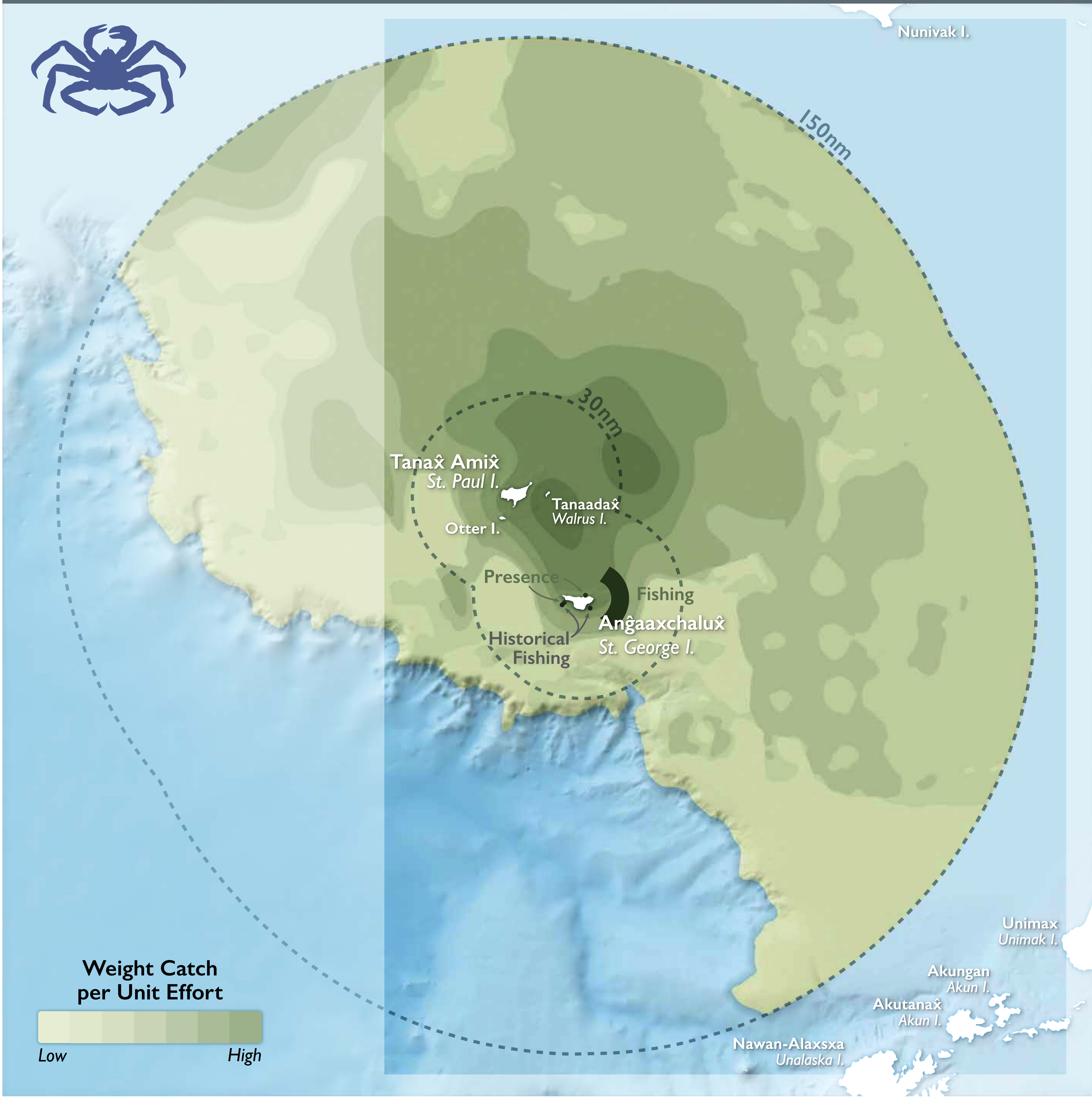
Blue king crabs (*Paralithodes platypus*) occur in disjunct population segments in the Bering Sea; the two major populations of blue king crab in Alaska are in the Pribilof Islands and in St. Matthew Island areas. Other population segments occur in the waters around the Diomede Islands, outer Kotzebue Sound, King Island, and outer Norton Sound. Adult blue king crabs consume a wide assortment of invertebrates including worms, clams, mussels, snails, brittle stars, sea stars, sea urchins, sand dollars, barnacles, crabs, other crustaceans, fish parts, sponges, and algae.

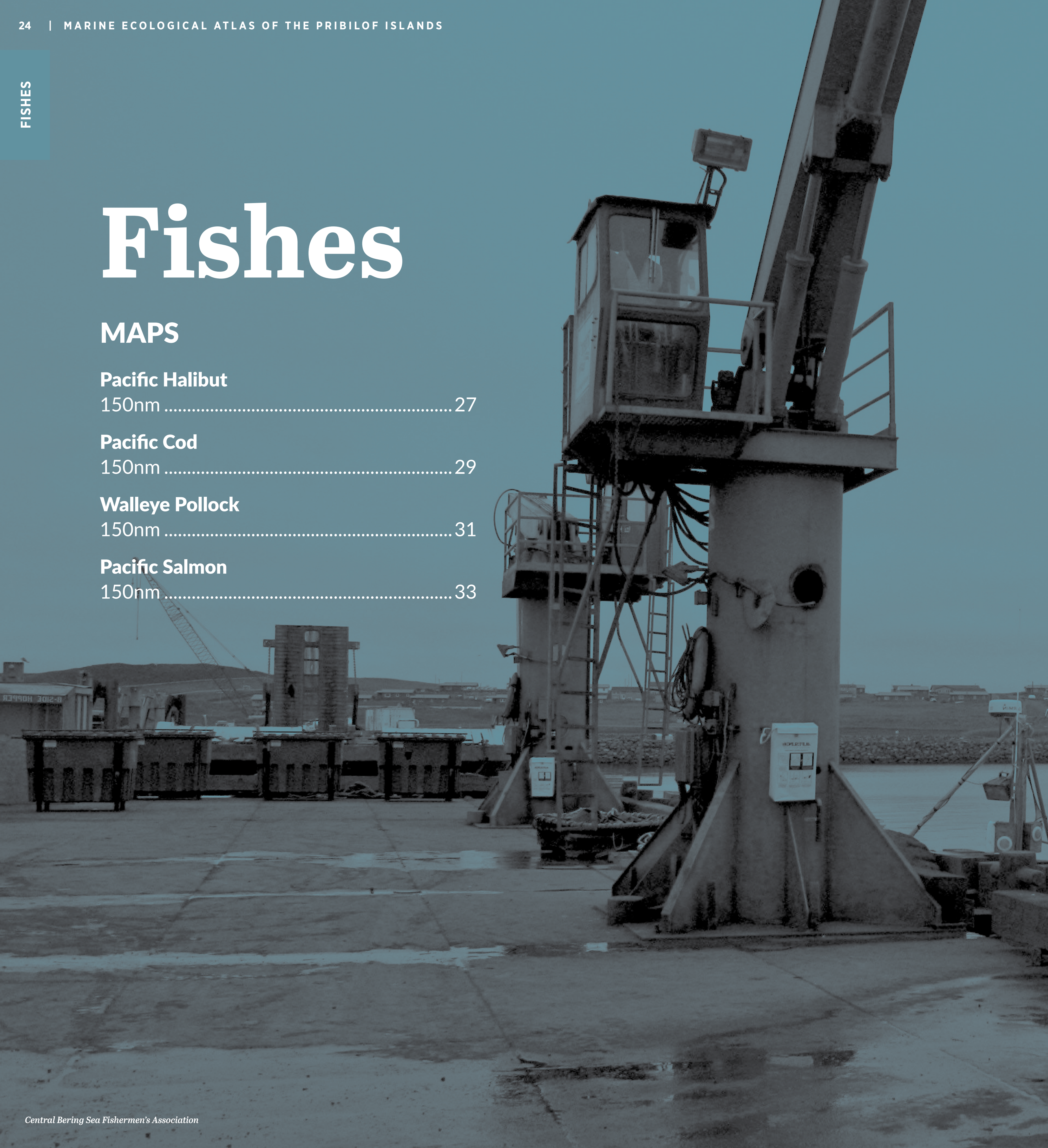
Blue king crabs have a complex life cycle that includes four planktonic larval stages, a semi-benthic post-larval stage, and benthic juvenile and adult stages (Daly et al. 2012). Blue king crab females brood their eggs for about a year (Stevens 2006a), and reproduce only once every two years (Jensen and Armstrong 1989; Somerton and Macintosh 1985). Mature females prefer nearshore areas, particularly during hatching (Armstrong et al. 1987; Watson 2008). Larvae are hatched in the spring (Stevens 2006b) and spend two to three months in the plankton before settling to the benthos and molting to the earliest benthic stages (Stevens et al. 2008). Early benthic phase juveniles have a strong affinity for habitats with complex physical structures (Armstrong et al. 1987; Jensen and Armstrong 1989), presumably to avoid predation or provide important foraging opportunities. Adult blue king crabs are found in more complex shell-hash and cobble habitats, as well as unstructured soft sediment (Armstrong et al. 1987; Blau 1996). Adult blue king crabs exhibit nearshore to offshore (or shallow to deep) annual migrations; adult females and some adult males molt and mate before they start their offshore feeding migration to deeper waters. Adult crabs tend to segregate by sex off the mating-molting grounds. Blue king crabs are seldom found co-existing with one another even though the depth ranges they live in and habitats may overlap.

The Pribilof Islands blue king crab stock was declared overfished in 2002 and does not show signs of rebuilding, despite being closed to directed harvest since 1999 (Daly et al. 2016). This stock is the only overfished stock in the North Pacific. In an effort to restore the Pribilof Islands blue king crab, State and Federal management actions were developed with input from stakeholders and managers through the North Pacific Fishery Management Council process. The Pribilof Island Habitat Conservation Zone was established in 1994 to exclude commercial trawling from waters around the Pribilof Islands known to serve as nursery habitat for blue king crabs. Other measures have been adopted to rebuild the population, including a prohibition on targeted Pribilof Islands blue king crab fishing and spatial closures in other crab and finfish fisheries that catch blue king crabs incidentally. Despite these efforts, no significant recruitment of blue king crabs has been observed since the stock was declared overfished and the population remains at a very low level. It is hypothesized that the primary predator of blue king crab, Pacific cod (*Gadus macrocephalus*), is responsible for continued crab recruitment failures (Livingston 1989).

150NM

Blue King Crab





Fishes

MAPS

Pacific Halibut

Pacific halibut (*Hippoglossus stenolepis*) is the largest teleost (ray-finned fish) in the North Pacific and an important predator in the Bering Sea marine ecosystem. They have a far-reaching distribution from northern Japan and the northern Bering Sea and south through the Gulf of Alaska (GOA) to California. They are abundant on the eastern Bering Sea (EBS) shelf, occurring at depths generally less than 1,000 feet (300 m) deep, though they can be found as deep as 3,600 feet (1,100 m). Adult halibut migrate annually from shallow summer feeding grounds on the EBS shelf to deeper areas to spawn from November to March, a pattern that begins as juveniles. This movement pattern is motivated by bottom temperature, with juvenile halibut following warmer water at the shelf edge in the winter and returning to the shelf flats after ice break-up in the spring (Best 1977). Pacific halibut spawn in both the GOA and the EBS and, because of currents, they are spread throughout and between both oceanic regions. Spawning in the EBS occurs along the shelf edge from Unimak Pass northward to Pervenets or Middle Canyon and westward along the Aleutians to Attu Island. Halibut spawned in the GOA can be transported into the EBS through Unimak Pass. They prefer shallow water, less than 165 feet (< 50 m) deep for their nursery habitat with muddy or fine sands to easily bury themselves for predator avoidance (Sohn 2016; Stoner and Abookire 2002; Wilson et al. 2016). Aside from Bristol Bay, Pacific halibut settle around Nunivak Island, along the Alaska Peninsula, and around the Pribilof Islands that border the inner and middle shelves of the EBS (Best and Hardman 1982; Sohn 2016). Pacific halibut are rarely found at temperatures below 32° F (0° C), instead preferring water near 36° F (2° C) to 39 °F (4° C; Best 1977). When they hatch, their eyes are symmetrical and they are about 0.4 inches long (11 mm), but in the 6 to 7 months it takes them to go from spawned egg to settled fish (about 0.8 inches (21 mm) in length, Pacific halibut undergo a distinct metamorphosis, with their left eye shifting to the right side of their heads (St. Pierre 1989).

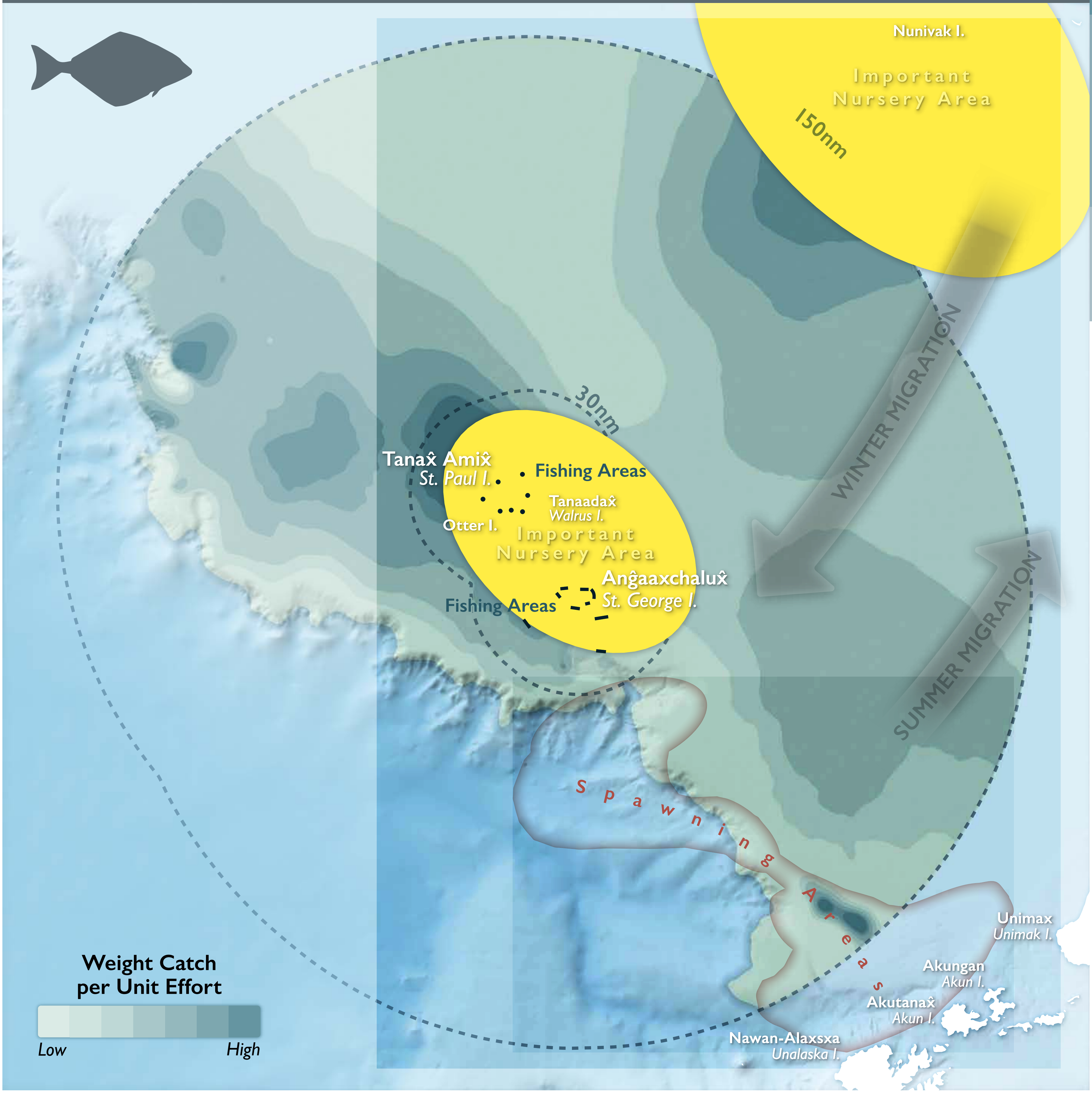
> "If we don't do something, then later on we'll pay the price for it and we'll have nothing. Because you know, it's getting pretty tough —the safety. I worry cause my boys are out there fishing. We have to go further out [for halibut] and we don't have the money for bigger boats. The larger commercial boats are right out here, east of the island. They used to stay between 6 and 12 miles and further."
>
> ~ M. Merculieff Sr.

Fish as large as Pacific halibut require a substantial amount of food. In maintaining their energetic needs, they can directly affect their prey populations with the sheer biomass they consume (Best and St-Pierre 1986). Halibut are visual predators, relying on both cues from prey and the activity of other halibut for success (Stoner and Ottmar 2004). Juvenile halibut prey upon small crustaceans, such as shrimp, small Tanner crabs (*Chionoecetes bairdi)*, snow crabs (*C. opilio*), and Pacific octopus (*Enteroctopus dofleini*). As they grow, larger Tanner crabs, red squid (*Berryteuthis magister*), and fishes including Pacific herring (*Clupea pallasii*), Pacific cod (*Gadus macrocephalus)*, walleye pollock (*G. chalcogrammus*), and Pacific sand lance (*Ammodytes hexapterus*) dominate their stomach contents (Best and St-Pierre 1986; Moukhametov et al. 2008). Pacific halibut are prey for marine mammals but rarely for other fishes (Best and St-Pierre 1986). Steller sea lions (*Eumetopias jubatus*) and killer whales (*Orcinus orca*) have been found with halibut in their stomachs (Best and St-Pierre 1986; John and Graeme 2006; Merrick et al. 1997), but a large adult halibut may be an apex predator in its own right.

Pacific halibut drive large-scale and local commercial and subsistence fisheries in the Pribilof Islands and how these fisheries divide such an important resource is often a point of concern for relevant stakeholders. In addition to the allocation of the Pacific halibut catch between halibut users in the EBS, there is also concern for limiting halibut bycatch mortality in trawl and longline fisheries. The timing and physical techniques of returning incidentally caught halibut affect their discard mortality rates (Williams 2015). In St. George, residents posit intensive trawl catches in nearby waters incidentally kill a substantial amount of halibut as bycatch (Lyons et al. 2016). Additionally, local fishermen participating in commercial fishing operations for halibut through the local Community Development Quota program have reported diminishing productivity in nearshore fishing grounds on St. Paul and St. George, evidenced as both reductions in size and abundance of halibut within 10 miles of the islands (Lyons et al. 2016). The current diminished average size of Pacific halibut and a declining "size at age" (expected size based on age of fish) are important conservation concerns (Clark and Hare 2002).

150NM

Pacific Halibut



Pacific Cod

Pacific cod (*Gadus macrocephalus*, family Gadidae) is one of the most well-known gadids, a family that includes walleye pollock (*G. chalcogrammus*), Atlantic cod (*G. morhua*), Arctic cod (*Boreogadus saida*), and saffron cod (*Eleginus gracilis*). All play important roles both ecologically and economically for Alaska fisheries. Pacific cod, or P. cod, make up the second biggest fishery in the eastern Bering Sea (EBS) and Gulf of Alaska (Witherell and Armstrong 2015). P. cod are also the largest of the 3 cod species found in the western Arctic, growing up to 4 feet (1.5 m) long (Mecklenburg et al. 2002).

Pacific cod have a wide distribution and are potentially more adaptable to changing conditions than other members of the Gadidae family. They are found throughout the North Pacific Ocean from southeast Alaska and the Gulf of Alaska, along the Aleutian Islands, and across the EBS shelf (Mecklenburg et al. 2002, North Pacific Fishery Management Council 2015b). There are an estimated 980 million Pacific cod in the EBS alone (North Pacific Fishery Management Council 2015b). They have also been reported as far north as the Chukchi Sea (Mecklenburg et al. 2002), an area that has historically been dominated by Arctic cod, and may become more abundant farther north as waters become more favorable for survival.

Pacific cod spawn in the late winter or early spring (Neidetcher et al. 2014), in deeper waters, but their larvae are positively buoyant so they float up near the surface and are pushed toward shallow nursery habitats by ocean currents (Rugen and Matarese 1988). Once they hatch in these shallower habitats, larvae hide from predators in eelgrass, *Zostera* spp. (Laurel et al. 2007). Eelgrass nursery habitats, as well as the right oceanic conditions and prey availability, are critical for survival (Moss et al. 2016). As they grow, P. cod begin schooling, and at two years of age, shift habitat preferences to areas with rough, rocky bottoms (Ueda et al. 2006). P. cod change locations within the Bering Sea throughout the year, moving deeper in the fall/winter and shallower in the spring/summer (Rand et al. 2014). They grow quickly, but unlike some fish that grow fast and mature early, P. cod can live up to 25 years (Munk 2001).

Pacific cod diets include snow crabs (*Chionoecetes opilio*) and Tanner crabs (*C. bairdi*), which make up over 20% of P. cod stomach contents (Livingston 1989). P. cod diets shift as they grow, from Chionoecetes crabs to larger red king crabs (*Paralithodes camtschaticus*) and fishes, including Pacific herring (*Clupea pallasii*), Atka mackerel (*Pleurogrammus monopterygius*), and arrowtooth flounder (*Atheresthes stomias*; Livingston 1993). P.cod serve as an important component of the diets of predators such as Pacific halibut (*Hippoglossus stenolepis*; Best and St-Pierre 1986) and Steller sea lions (*Eumetopias jubatus*; Sinclair and Zeppelin 2002).

Pacific cod was the first commercially fished species in the EBS (Fredin 1985), beginning in the days of wooden schooners, and is now harvested using trawls, longlines, jigs, and pots (North Pacific Fishery Management Council 2015b). While more Walleye pollock are caught in the EBS annually, the value of P. cod is greater (measured as wholesale value per ton) than pollock, yellowfin sole (*Limanda aspera*) and Pacific ocean perch (*Sebastes alutus*) combined (North Pacific Fishery Management Council 2015a). P. cod are sold for fillets and are a popular alternative for Atlantic cod in European markets (North Pacific Fishery Management Council 2015a)

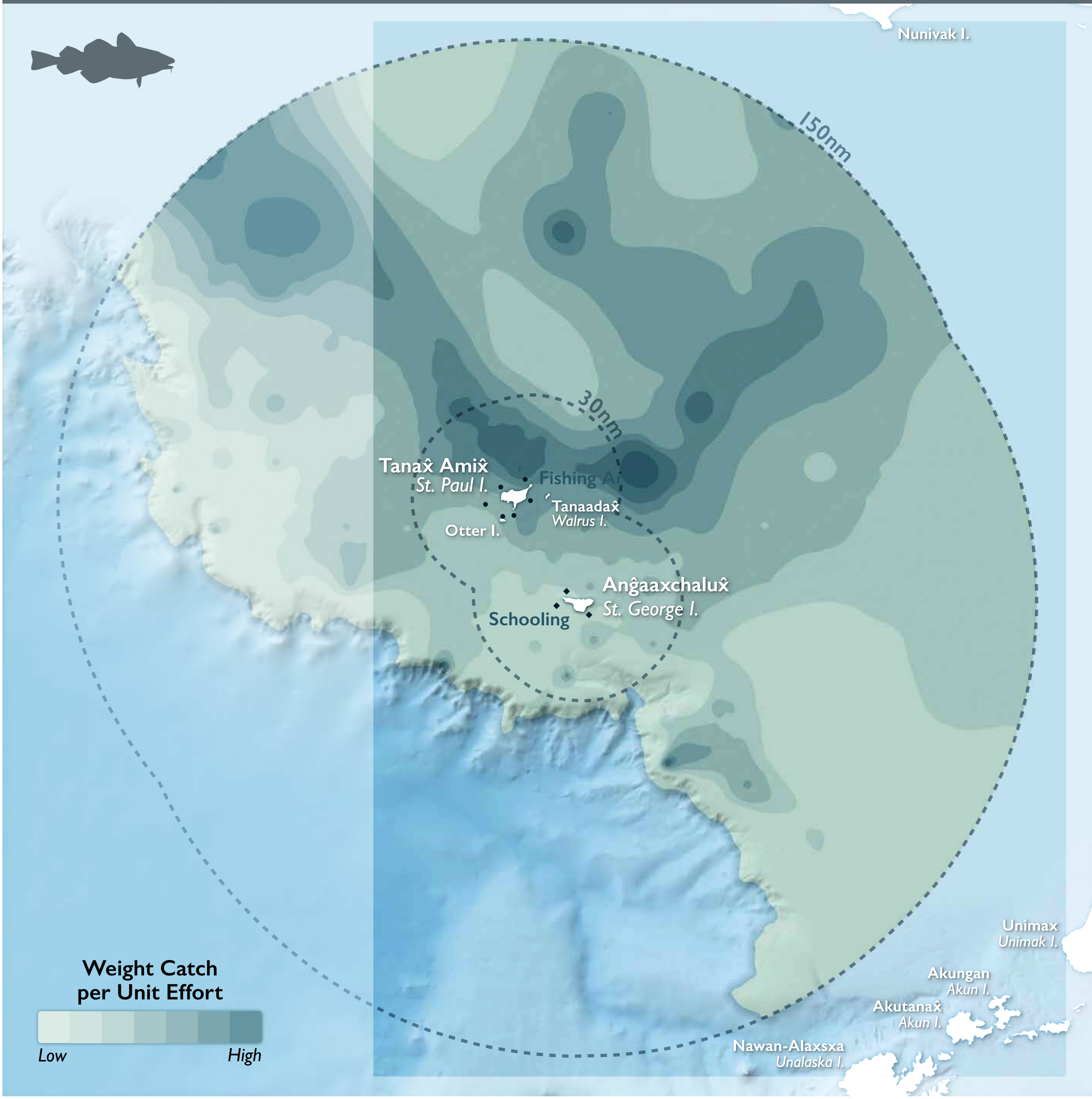
"My grandparents used to catch cod for us to eat out a couple miles from shore."

~ R. Warner

Adobe Stock

150NM

Pacific Cod



Walleye Pollock

Walleye pollock (*Gadus chalcogrammus*) are ubiquitous in the North Pacific Ocean and range from the coastal waters of the Pacific Northwest through the Gulf of Alaska and along the Aleutian Islands in the south, to the Sea of Okohtsk and Sea of Japan in the west, and through the Bering Strait to the Chukchi Sea in the north. Walleye pollock are the most abundant groundfish species in the eastern Bering Sea (EBS) and all stages of the pollock life cycle provide important links between lower trophic levels and the seabirds and marine mammals at the top of the Bering Sea food web. Larval and juvenile pollock are preyed upon by other fishes and seabirds, while juvenile and adult pollock are major prey for marine mammals (Livingston 1993). Juvenile pollock eat zooplankton like pteropods (sea snails) and copepods (Moss et al. 2016; Siddon et al. 2014) while adults prey largely on krill (Brodeur et al. 2002; Ciannelli et al. 2004) and myctophids (lanternfish; Barbeaux et al. 2016). Pollock also cannibalize smaller, younger pollock, and this predation can regulate the population (Laevastu and Favorite 1988). Other fish, marine mammals, and seabirds also rely on pollock as an important food source (Livingston 1991, 1993; Whitehouse 2013). It is estimated that marine mammals alone eat over half a billion pollock (300,000 metric tons; 331,000 US tons) in the EBS each year (Perez and McAlister 1993).

In a given year, however, pollock diet in various life stages is largely dependent on what is available in the water column, and the EBS zooplankton assemblage is dependent on the timing of the annual winter sea-ice retreat. There is a spatial alignment of primary production, zooplankton and age-0 pollock in cold years and a mismatch in warm years (Coyle et al. 2011; Hunt et al. 2011; Sigler et al. 2016). Larger, lipid-rich copepods and euphausiids are often more abundant in cold years with late ice retreat than in warm years with early ice retreat (Coyle et al. 2008). Young pollock consume these prey when available, better preparing them for surviving over their first winter (Coyle et al. 2011; Hunt et al. 2011; Sigler et al. 2016).

Consistent pollock spawning areas of the Bering Sea include the southeastern Bering Sea outer shelf, in particular, northeast of Unimak Pass, and northwest of the Pribilof Islands. After hatching, young-of-the-year pollock utilize open water shelf habitats and can typically be found between 165 and 650 ft (50 and 200 m) depth, depending on the water temperature. Pollock are a relatively fast-growing fish (Laurel et al. 2016; North Pacific Fishery Management Council 2015b), and can grow to 9 pounds (4 kg; Hinckley 1987).

Pollock meat is marketed for a wide variety of foods, from fish sticks to imitation crabmeat used in sushi rolls. Demand for these products has made walleye pollock the largest groundfish fishery in Alaska and one of the largest single-species fisheries in the world (Witherell and Armstrong 2015). A large network of seafood companies, fishing vessels, factory trawlers, processors, wholesalers, employees, and communities rely on pollock for revenue (North Pacific Fishery Management Council 2016). Pollock catches in the Bering Sea average between 1 and 1.5 million metric tons (1.1 to 1.7 million US tons) each year (North Pacific Fishery Management Council 2015a). Globally, pollock represents over 40% of whitefish production (North Pacific Fishery Management Council 2014). Approximately 120 fishing vessels, including 30 large factory trawlers, fish for pollock in the Bering Sea (North Pacific Fishery Management Council 2016). Fishing occurs almost year-round; an 'A-season' fishery runs from January through mid-April annually, with a focus on catching pre-spawning female pollock for their roe (eggs). 'B-season' fishing opens in June and ends at noon on November 1st annually (North Pacific Fishery Management Council 2015a).

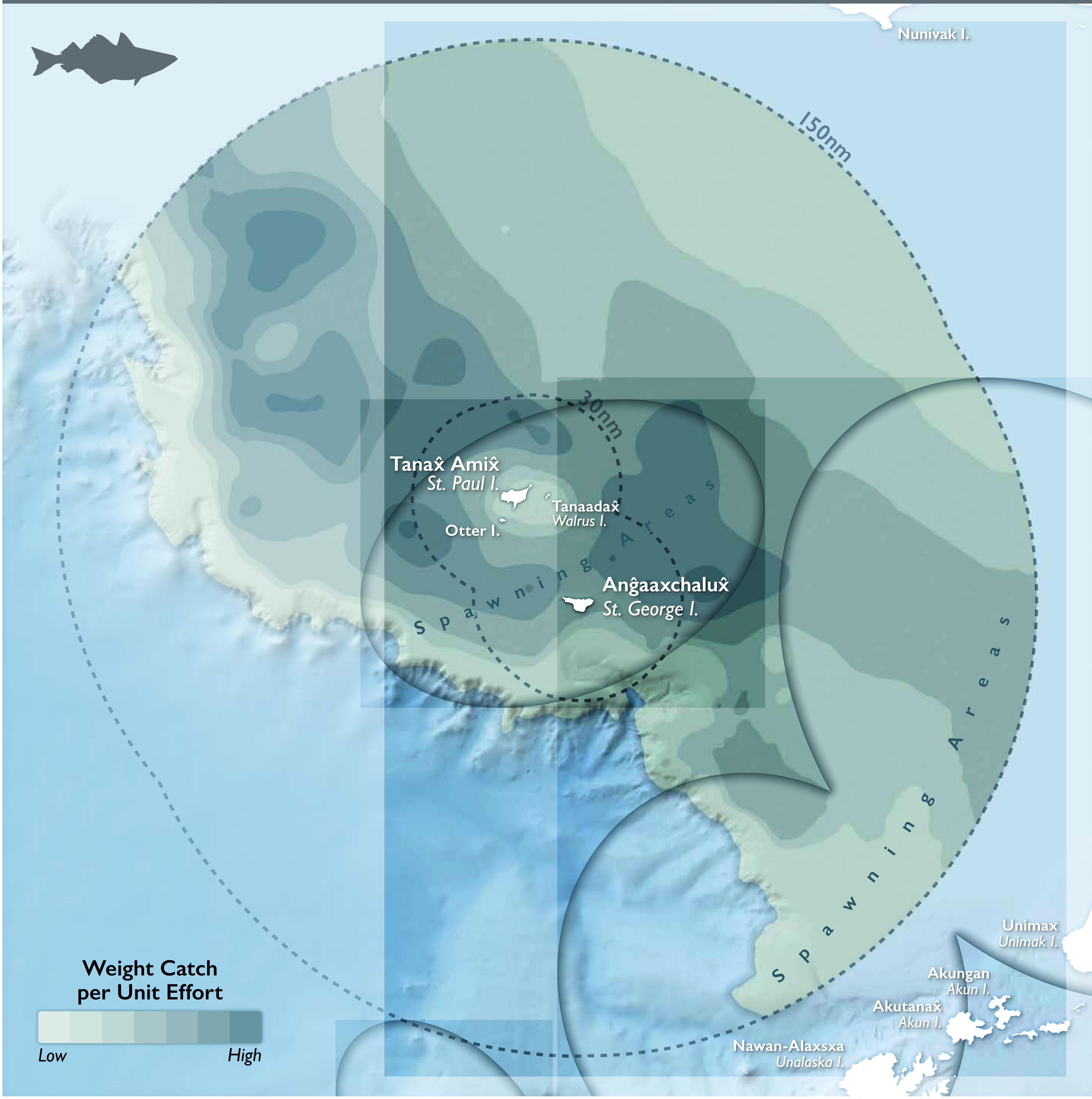
A major concern surrounding the management of the pollock fishery is the competition with fish-eating marine predators, particularly Steller sea lions (*Eumetopias jubatus*) and northern fur seals (*Callorhinus ursinus*; see Steller Sea Lion and Northern Fur Seal summaries in the Marine Mammals Chapter). As Steller sea lions are listed as Threatened by the Endangered Species Act, conservation measures have been put into place to reduce possible interactions with commercial fishing vessels and competition for resources, including area closures and seasonal fishery limits in Steller sea lion critical habitat within the Bering Sea, including the Pribilof Islands (North Pacific Fishery Management Council 2015a). The communities of St. George and St. Paul islands are also concerned with similar possible interactions with commercial fishing vessels and competition for resources for northern fur seals, listed as depleted under the Marine Mammals Protection Act. Another concern is the potential impacts of the pollock fishery on seafloor habitat and benthic communities. The fishery uses pelagic trawl gear to catch pollock, which is meant to catch fish in the water column. In practice, however, the gear routinely drags along the seafloor when fishing near the bottom, damaging seafloor habitat and resulting in bycatch of benthic and epibenthic species. Evidence of this damaging practice is recorded by observers who regularly note the presence of benthic invertebrates like crabs, snails, starfish, sea whips, and sponges in the catches (Ianelli et al. 2016).

A recent estimate of the walleye pollock population concluded that there are approximately 19.5 billion individual pollock (11.3 million metric tons; 12.5 million US tons) over the age of 1 in the EBS (North Pacific Fishery Management Council 2015a). However, the pollock population is depressed due to the effects of commercial fishing; if the population were left unfished, there would be an estimated 31.3 billion pollock in the Bering Sea (North Pacific Fishery Management Council 2015a).

150NM

Walleye Pollock

FISHES | WALLEYE POLLOCK | 150NM



Pacific Salmon

Five species of Pacific salmon inhabit the cold waters of the Bering, Chukchi and Beaufort Seas: Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha)*, and chum salmon (*O. keta*). Each species has unique life history characteristics but they are all anadromous fishes that move from fresh water to salt water and back to freshwater habitats during a normally completed life cycle. The ocean range for all five species of Pacific salmon encompasses the Gulf of Alaska and the eastern and northern Bering Sea, with chum and pink salmon being the only species regularly seen in the Arctic. Chum are the most widely distributed of the five species. Like chum salmon, Chinook range widely from California to the Bering Sea, returning to the coasts of both North America and Asia. The major Alaska populations are from the Yukon-Kuskokwim River Delta, with some juvenile Chinook migrating toward Norton Sound before heading offshore. Sockeye salmon dominate the offshore areas of the southern Bering Sea and Bristol Bay, with juveniles rarely found north of the northern Bering Sea. Juvenile cohos are found nearshore, adjacent to the Kuskoskwim River Delta.

The ability for a fish to move between fresh water and the marine environment is physiologically taxing. In order for juvenile salmon to make the transition from freshwater streams to the ocean, they must undergo "smoltification," which involves changes in their coloration, morphology, physiology, osmoregulation, and behavior (Stefansson et al. 2008). Once they make the journey back to fresh water as adults, the transition is so energetically expensive that they stop feeding and focus exclusively on returning to streams to spawn (Groot and Margolis 1991). In doing so, they begin to decompose from the inside out and quickly die after spawning (Groot and Margolis 1991; Hendry and Berg 1999). The life-history trait of spawning only once is known as "semelparity" and distinguishes Pacific salmon from Atlantic salmon (*Salmo salar*), which are "iteroparous," and can spawn multiple times within their lifetime (Marschall et al. 1998).

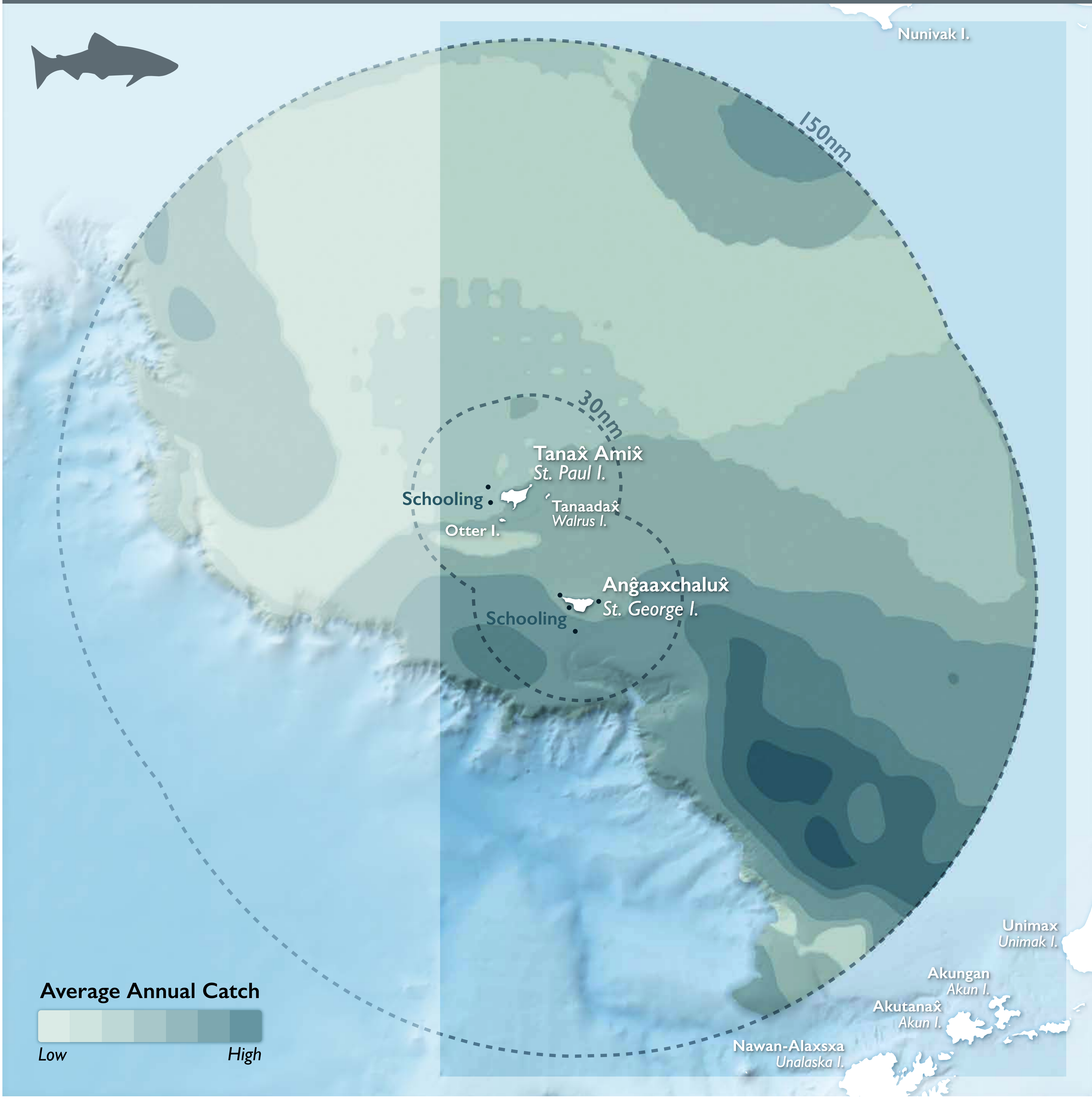
All five species of Pacific salmon can be found during their marine phases foraging in the eastern Bering Sea (EBS). However, climate change is negatively affecting salmon populations as the oceans become more acidified. Ocean acidification negatively impacts pteropods (sea snails), a primary prey item for some species of salmon, as well as other prey items with calcareous (calcified) body parts (Fabry et al. 2009; Kawaguchi et al. 2010; Long et al. 2013; Orr et al. 2005). The linkage between freshwater and marine ecosystems during the salmon lifecycle connects the Pribilof Islands to the Alaskan communities where salmon are vitally important. All five species have been observed in the nearshore waters of St. George and St. Paul, and spawning and non-spawning chum, pink and sockeye salmon have been caught in recent years on St. Paul, confirming they occur in the area, probably foraging during the late summer and early fall months before returning to their natal streams to spawn. The frequency, timing, and abundance of salmon observed by Pribilof community members varies, with some years yielding observed high abundances of salmon nearshore and in brackish bays that may appear unpredictably between June to early September, and some years yielding only a few stray spawning phase salmon.

V. Padula

Salmon are not known to spawn on the Pribilof Islands as there are no surface freshwater streams or rivers, but are seen regularly in the marine waters surrounding the islands. Residents enjoy fishing chum, pink and sockeye salmon that occur in the Salt Lagoon on St. Paul Island.

150NM

Pacific Salmon



Mammals

MAPS

V. Padula

Subsistence Mammals of the Pribilof Islands

The prehistoric users of the Pribilof Islands created one of the world's most specialized and successful maritime hunter-gatherer traditions, lasting from roughly 4000 BP to the time of Russian contact in 1741 (Dall 1877, 1878; Hrdlička 1945; Jochelson 1925; Lantis 1970; Lantis and Damas 1984; Laughlin 1980; McCartney 1984; Veniaminov and Black 1984). The Indigenous Peoples, known among themselves by regional autonyms, became known to their historical colonizers as 'Aleuts'. Today, the Indigenous Peoples collectively sharing the time honored bond of living together on St. George and St. Paul islands prefer to be called Unangax̂ (singular) or Unangan (plural collective; Corbett 2016). Unangax̂ oral tradition holds that Indigenous Peoples that inhabited more permanent villages in the Aleutian Islands had known of and utilized the Pribilof Islands for some time before their documentation by the Russians (Black 2004; Elliott 1882; Jochelson 2002; Osgood et al. 1915; Veniaminov and Black 1984). Prehistoric culture across the Aleutian Islands was based almost entirely on marine resources, including hunting all marine mammal species found throughout the region, trips to the Pribilof Islands of St. George and St. Paul, fishing the offshore and coastal waters, foraging for fish and shellfish on the rocky reefs, and hunting birds on land and sea. The wealth of resources supported dense human populations across the Aleutian Islands expressing a rich, strong culture. Virtually every archaeologist and ethnographer of the Aleuts have described what was hunted and how people used marine mammals, birds, fish, and shellfish (Corbett 2016).

Russian "discovery" of the Pribilof Islands occurred in 1741 by navigator Gerasim Pribylov. Pribylov's drive to locate the islands is attributed to a legend told him by a shaman on Unalaska Island, in which a young man from Unimak Island—*Iggadaagix̂*, son of an Unimak *toion* (a member of the ruling class) by the name of *Akkagnikax̂*—was out hunting in his *baidarka* (kayak) before being blown to the islands by a storm (Elliott 1882:8; Torrey 1980:43).

> *"He had been forced to commit himself to the mercy of the wind and had, so it seems, after three or four days, been carried to the island of St. Paul, the northernmost of the Pribilof Islands. He remained until spring, hunting various animals including marine mammals and seabirds. In the spring, during clear weather, he saw the peaks of Unimak and decided to put to sea and, after a voyage of three or four days, safely reached his native Unimak, bringing with him many sea otter tails and skins"* (Veniaminov 1984:134–135).

Another Unangax̂ legend of the Pribilof Islands was told to archaeologist Waldemar Jochelson in 1910, in which St. Paul Island is identified as "*Tanax̂ Amix̂*" Or "Land of Mother's Brother (Uncle)" (Jochelson 2002:76).

Even after Russian occupation and enslavement of Unangan for the purpose of harvesting *Laaqudan* (or northern fur seal, *Callorhinus ursinus*) pelts on the Pribilof Islands (Black 1983; Torrey 1983), the predominance of species in Unangax̂ subsistence, despite the availability of Russian foodstuffs, demonstrates the maintenance of cultural traditions during a time of intense colonialism. Marine mammals continue to serve as cornerstones of Pribilovian Unangax̂ culture and traditional ways of living. The tribal communities self-identify as 'People of the Seal' and live with the knowledge that, "If they're [seals] not here, then we won't be either" (resident interview, 2011). Given their irreplaceable value to the Pribilof Islands communities, the federally recognized tribes, called the Aleut Communities of St. George and St. Paul Island, have partnered with the National Marine Fisheries Service (NMFS) since the early 2000s through co-management agreements, seeking to incorporate equitable participation by Unangan of the Pribilof Islands in all decisions affecting the management and research of marine mammals used for subsistence purposes.

Among the most important subsistence resources available to Pribilovian Unangan is *Laaqudax̂*, the northern fur seal. During the era of intense commercial seal harvest, Unangan were allowed to take a portion of the meat and organs from commercially harvested fur seals for subsistence use (Osgood et al. 1915). Commercial harvest ended in the 1970s on St. George and in 1984 on St. Paul, necessitating an emergency federal rule to authorize subsistence take in the absence of commercial take. These rules intended to ensure compliance with the Fur Seal Act and Marine Mammal Protection Act. These regulations continue to limit subsistence practices of harvesting fur seals today. Unangan have traditionally and historically engaged in subsistence hunting (with firearms) of young male fur seals in the spring and winter, and subsistence harvesting (using clubs) of *Laaqudaadan* (northern fur seal pups) in the fall. The overwhelming importance of *Laaqudaadax̂* as a subsistence resource can be seen in the archaeofaunal assemblage which demonstrates the antiquity of pup harvesting by the Pribilof Unangax̂ (Eldridge 2016).

Until recently, take of *Laaqudan* in the Pribilof Islands was authorized only with the use of the Russian commercial harvest method, not the traditional methods of Unangax̂. This method involves organized herding of sub-adult males at a specific haulout area by 5 to 10 people, called sealers. Once animals are herded, the sealers quickly form a line between the shore and the seals to prevent fur seal access to the ocean. Seals are then slowly guided and moved from their haulout areas to a specific grassy area, long ago designated as a 'killing field,' where they are held in a large group by a handful of individuals known as watchers. A smaller group of seals are then separated from the large herded group and walked towards 3 to 4 sealers (called clubbers) who stun the seals by hitting them on the skull with a solid wooden club. The seals are pulled a short distance away from the 'killing area' after they are stunned (knocked unconscious) where the chest and heart are immediately cut open by the harvester, allowing exsanguination and a humane death. The seals are then skinned and butchered and bagged in the field. Meat, organs, and fore flippers are consumed as subsistence foods or used for traditional crafting, and occasionally blubber is rendered for seal oil. Hunting with firearms occurs on St. Paul from January 1 – May 31 annually.

Another irreplaceably important subsistence resource of the Pribilof Islands is the Steller sea lion. Sea lion pups are particularly enjoyed by subsistence users in the Pribilof Islands. For example, pups and juveniles accounted for 96.5% of the minimum total animals recovered from a Zapadni archaeological site in 2001/2002 (Eldridge 2016). Historical research indicates that adults were also sought as a major source of raw materials (e.g., for skins for baidars; Elliot 1882; Osgood et al. 1915). Adult sea lions were hunted primarily during the summer, with the largest number of animals taken in July and August (Veltre and Veltre 1981).

Sea lion hunting is exclusively a land-based activity; pelagic hunting of sea lions does not occur. Subsistence hunters primarily target pup (age 0) and juvenile (age 1-2 years) sea lions; adult sea lions (3+ years old) are not targeted. Sea lions are primarily hunted while they are swimming nearshore, but sometimes are hunted while hauled out on land, using high-powered rifles (.22-250 to .300 caliber) fired from traditional hunting blinds or other vantage points. The methods used for hunting sea lions from land vary depending on several factors, including but not limited to: time of year, hunting location, presence of other marine mammals, whether the animal is on land or in the water, and weather conditions. Hunting sea lions that are swimming from a land-based vantage point requires extensive local knowledge of several behavioral characteristics of sea lions and their habitat.

Steller sea lions hunted in the water can sink quickly when shot, making them difficult to recover. However, if the Steller sea lion is able to be retrieved immediately, hunters use a special process to recover the animal. To recover animals from water, hunters use a *qayux̂* (retrieving hook or 'sea dog', pronounced 'kī-yōō') to hook the animal in the water and pull it towards shore. A *qayux̂* consists of a wooden grappling or throwing hook attached to a length of rope that is thrown from shore and used to snag and retrieve the sea lion. Every hunter makes his or her own *qayux̂*. If a struck sea lion is not able to be retrieved immediately (due to quickly sinking animal), the hunter will attempt to actively track the struck animal for up to three days. Over this three-day period, tracking includes monitoring local currents and wind speeds to predict where the animal could wash ashore after floating back to the surface. Hunters then monitor the shoreline in these areas during daylight hours at both high and low tide to locate the sea lion when it drifts ashore. A hunter that has struck a sea lion but did not retrieve it will notify other hunters in the community to increase the odds of detecting the wounded animal or carcass onshore. After the third day, even in the cold Bering Sea waters, the meat will begin to decompose to the point that it is not safe to consume. Animals that are not recovered within this timeframe are reported as struck and lost to the appropriate local managing agencies on each island.

Other Marine Mammals used for Subsistence

Historical records show that polar bears (*Ursus maritimus*) were occasionally captured during the winter on the Pribilofs, but this species has not been seen on the islands since the early Russian period (Hanna 2008:190).

Hair seals, including spotted (*Phoca largha*), ringed (*Pusa hispida*), and harbor seals (*Phoca vitulina*), can be found in the Pribilof Islands throughout the year (Hanna 2008:186). Bearded (*Erignathus barbatus)* and ribbon seals (*Histriophoca fasciata*) are not as common (Hanna 2008:189) and are very rarely encountered as stranded carcasses on the shorelines.

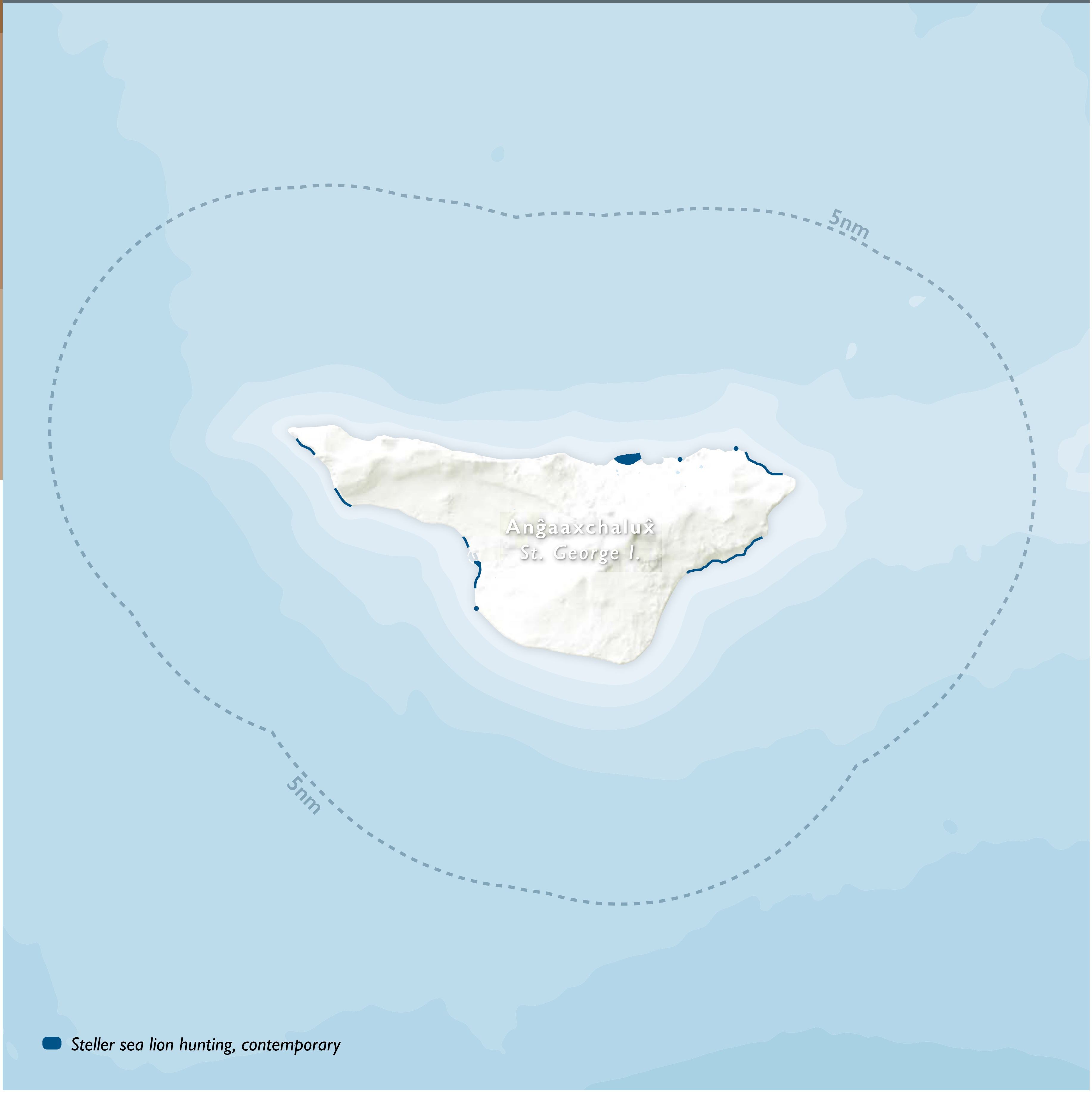
Historically, residents of the Pribilof Islands harvested whales that washed ashore as a subsistence resource for food and to build their subterranean homes, called barabas. Today, cetaceans are commonly observed alive, and occasionally as drift carcasses, near the islands, including the bowhead whale (*Balaena mysticetus*), North Pacific right whale (*Eubalaena japonica*), blue whale (*Balaenoptera musculus*), sperm whale (*Physeter catodon*), fin whale (*Balaenoptera physalus*),humpback whale (*Megaptera novaeangliae*), and orca (*Orcinus orca*) (Hanna 2008:192; MacDonald and Cook 2009).

"We told a biologist, 'Hey, you know fur seals are declining?' and they said they were doing studies on St. Paul. I said, 'You're on the wrong island to study. You should be over here where they're declining. I said, 'We see it with our own eyes. Same with birds. If we miss one bird we'll notice it.'"

~ M. Merculieff Sr.

ST. GEORGE 5NM

Subsistence Mammals



ST. PAUL 5NM

Subsistence Mammals

CITY of ST GEORGE · ALEUT COMMUNITY OF ST. PAUL TRIBAL GOVERNMENT · Audubon | ALASKA

Northern Fur Seal

Laaqudan or northern fur seals (*Callorhinus ursinus*) are central to Pribilovian Unangax̂ culture and is the main staple traditional food of the islands (see Subsistence Mammals of the Pribilof Islands on page 36). The Eastern Pacific stock of *Laaqudan* is one of five recognized stocks that occur and breed on six island groups throughout the North Pacific (Dizon et al. 1992). During the summer breeding season, the majority of the worldwide population is established on the Pribilof Islands (Gentry 1998). Since 1998, pup production on St. Paul Island, which drives the overall stock health, has declined by 57.7%, at an annual rate of 4.09% (SE ± 0.34; Towell et al. 2018). In 1988, the species was listed as depleted under the Marine Mammal Protection Act (MMPA) because population levels were less than 50% of the historical abundance of 1.8 million animals (53 FR 17888, 18 May 1988). To fulfill its obligation under the MMPA, the National Marine Fisheries Service (NMFS) developed a Conservation Plan intended to conserve and restore the species to its optimum sustainable population of between 1.2-1.8 million animals (NMFS 1993, 2007). Since the implementation of the Conservation Plan, a significant amount of research has been conducted on fur seals related to topics including seasonal foraging ecology, pup production, adult male counts, size-at-age estimates, mortality rates at various life history stages, and disease. Despite the intensive efforts and cooperative involvement of tribal, state, and federal governments; academia; the fishing industry; and non-governmental agencies over the past decades, Pribilof Islands northern fur seals, particularly on St. Paul, remain in a state of decline. Understanding the reasons for the decline of the Pribilof Islands stock is of vital importance to the Pribilof Communities and a range of stakeholders with interests in the Bering Sea, including fisheries managers, the fishing industry, conservation agencies, and other stakeholder groups.

The incredibly unique—and contentious—history of the commercial harvest of *Laaqudan* from the 18th to 20th centuries has certainly contributed to the abundance declines of the Pribilof Islands segment of the population. Beginning with the Russian discovery of northern fur seals on the Pribilof Islands in 1742, the animals have been exploited for their pelts. Russian explorers enslaved Unangan hunters from Unalaska and Umnak Island for the purpose of harvesting pelts (Black 1983; Torrey 1983). Forced commercial harvests continued in the Pribilof Islands after the purchase of Alaska by the U.S., first under the Alaska Commercial Company, then the Northern Commercial Company, and finally under the U.S. Department of Fisheries (Rubicz 2007). During the peak of commercial harvesting from the early 1940s to 1968, up to 126,000 animals were harvested annually (NMFS, unpublished data).

Males are territorial and most return to the rookeries where they were born to breed (Gentry 1998). Reproductive males begin to compete for territories on the rookeries when about seven to nine years old (Johnson 1968), but recent evidence suggests younger males are beginning to defend territories successfully (NMFS, unpub. data). Females become sexually mature between 4 and 7 years old (York 1983) but can remain reproductive up to at least the age of 23 (Lander 1981). Females also tend to return to the rookeries at which they were born, but an unknown

Non-breeding males congregate on the sandy shorelines of St. Paul and St. George in areas called 'haulouts' away from the breeding grounds.

L. Divine

amount of temporary and permanent emigration occurs, with females moving to non-natal rookeries on the natal island or to other breeding islands (i.e., St. Paul, St. George, Bogoslof Islands; NMFS, pers. comm.).

Males arrive on rookeries in mid-May and females begin to arrive in mid-June (Gentry 1998). The males do not eat while defending their territories and lose up to a quarter of their body mass over this time period (Gentry 1998). Pregnant females give birth to a single pup within 2 days of arrival on shore, and then mate with the dominant male of the territory 3 to 8 days later (Gentry 1998). Females experience delayed implantation, with the fertilized egg implanting months later in early winter while the females are at sea (York and Scheffer 1997).

After giving birth to a pup, mothers leave the rookery to forage at sea and return to the rookery to nurse. They spend 3 to 10 days at sea foraging, depending on how long it takes to find enough food, then return to the rookery for one to two days to nurse. The length of the females' foraging trip, and hence the frequency of pup nursing, can influence the rate of pup growth, as seen in the related Antarctic fur seal (Lunn et al. 1993). Pups are weaned after about four months and then must forage on their own. Pups spend 22 months at sea before returning to their natal rookeries as 2 year olds.

Laaqudan distribute widely through the Pacific when they leave their summer breeding rookeries. After the pups are weaned in September, females leave the rookeries and migrate south, traveling through the passes in the Aleutian Islands and into the central North Pacific, Gulf of Alaska, and California Current (Ream et al. 2005). Older males remain in the Bering Sea longer and do not migrate as far south as the females (Loughlin et al. 1999; Sterling et al. 2014). Unimak Pass is a primary migration corridor, used twice a year as the animals leave and return to the Bering Sea (Ragen et al. 1995). In the winter, the females can be found dispersed from southern California to the Sea of Okhotsk and southern Japan off Asia (Kajimura and Loughlin 1988; Pelland et al. 2014; Ream et al. 2005). Pups disperse from the Pribilofs after weaning in autumn each year, and remain at sea for the first two years of life (Ragen et al. 1995; Zeppelin et al. 2019). This time period is hypothesized to be critical for pup survival and evidence suggests that increasingly variable climatic conditions at weaning, particularly timing, frequency and intensity of autumnal storms in the Bering Sea, may alter timing, direction of dispersal and potentially survival of pups (Lea et al. 2009).

Laaqudan rely on schooling forage fish, walleye pollock (*Gadus chalcogrammus*), and squid species, which varies by location and season (Gudmundson et al. 2006; Kuhn et al. 2014; Ream et al. 2005; Robson et al. 2004; Sinclair et al. 1994). In contrast, *Laaqudan* occurring on Bogoslof Island feed predominantly on deep-sea smelt bathylagids, northern smoothtongue (*Leuroglossus schmidti*), and gonatid squid (Kuhn et al. 2014) at night when the prey field migrates near the water surface. In the winter and spring, as they range throughout the North Pacific, female fur seals feed on Pacific herring (*Clupea pallasii*), capelin (*Mallotus villosus*), sablefish (*Anoplopoma fimbria*), Pacific sand lance (*Ammodytes hexapterus*), walleye pollock, and squid in the Gulf of Alaska and off British Columbia, and Pacific hake (*Merluccius productus*), northern anchovy (*Engraulis mordax*), market squid (*Doryteuthis opalescens*), Pacific herring, and rockfish (*Sebastes* spp.) off the coasts of Washington, Oregon, British Columbia and California (Antonelis and Perez 1984; Ream et al. 2005).

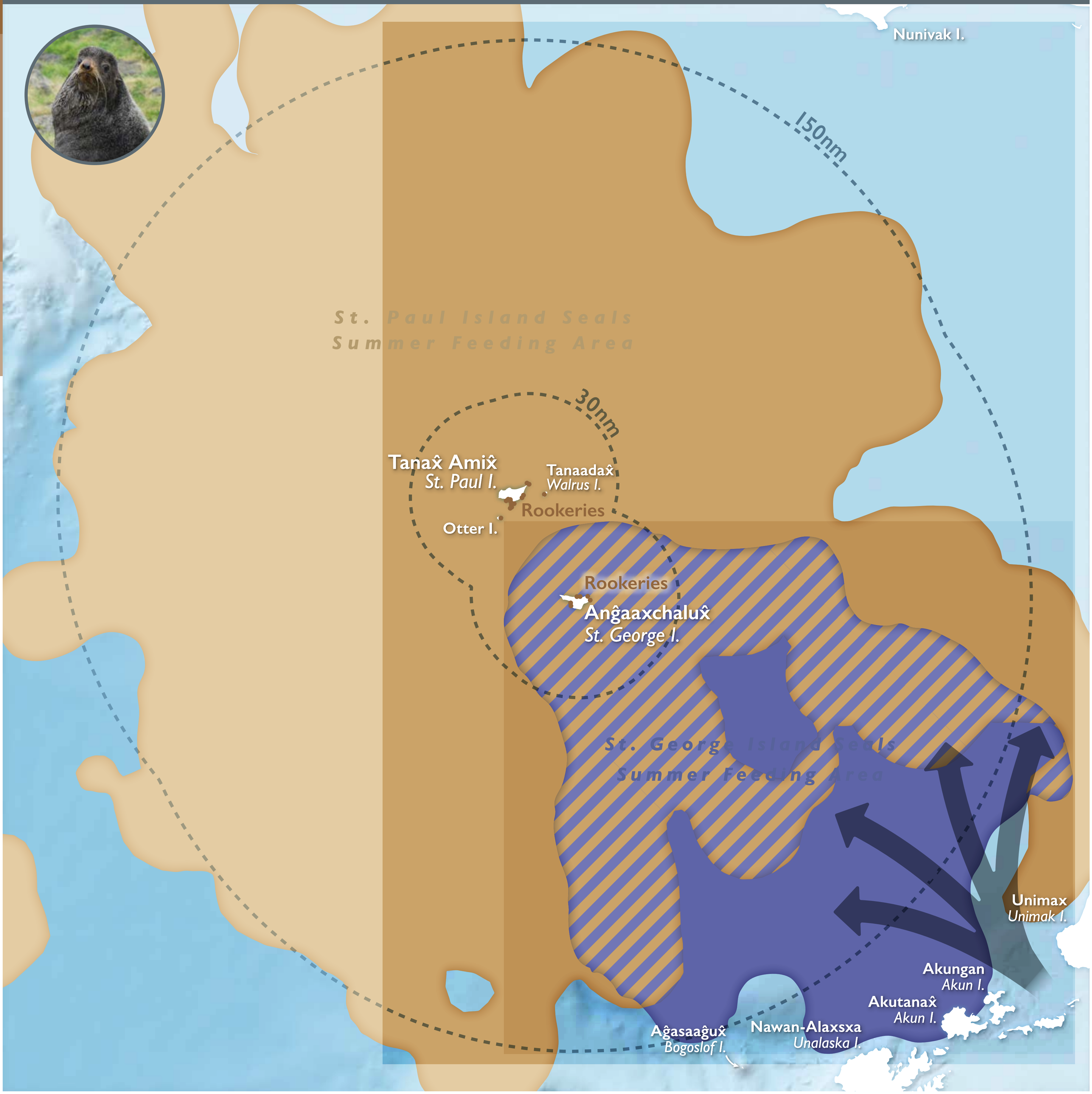
"We rarely did pup harvest; we'd get [pups] maybe a couple times when the season's ready, but not very many. We were always told we couldn't do it."

~ R. Warner

150NM

Northern Fur Seal

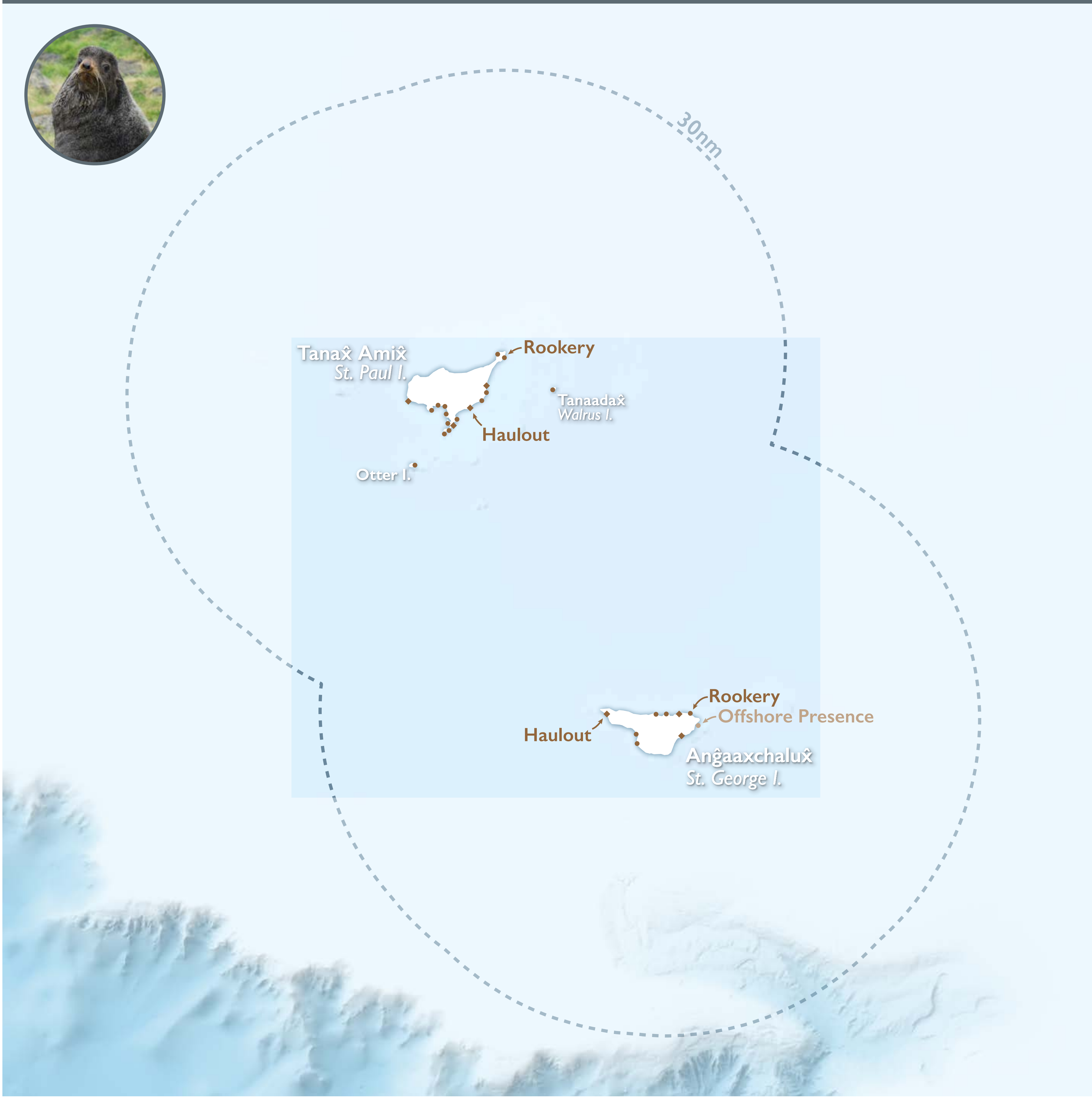
CITY of ST GEORGE
ALEUT COMMUNITY OF ST. PAUL TRIBAL GOVERNMENT
Audubon | ALASKA



30NM

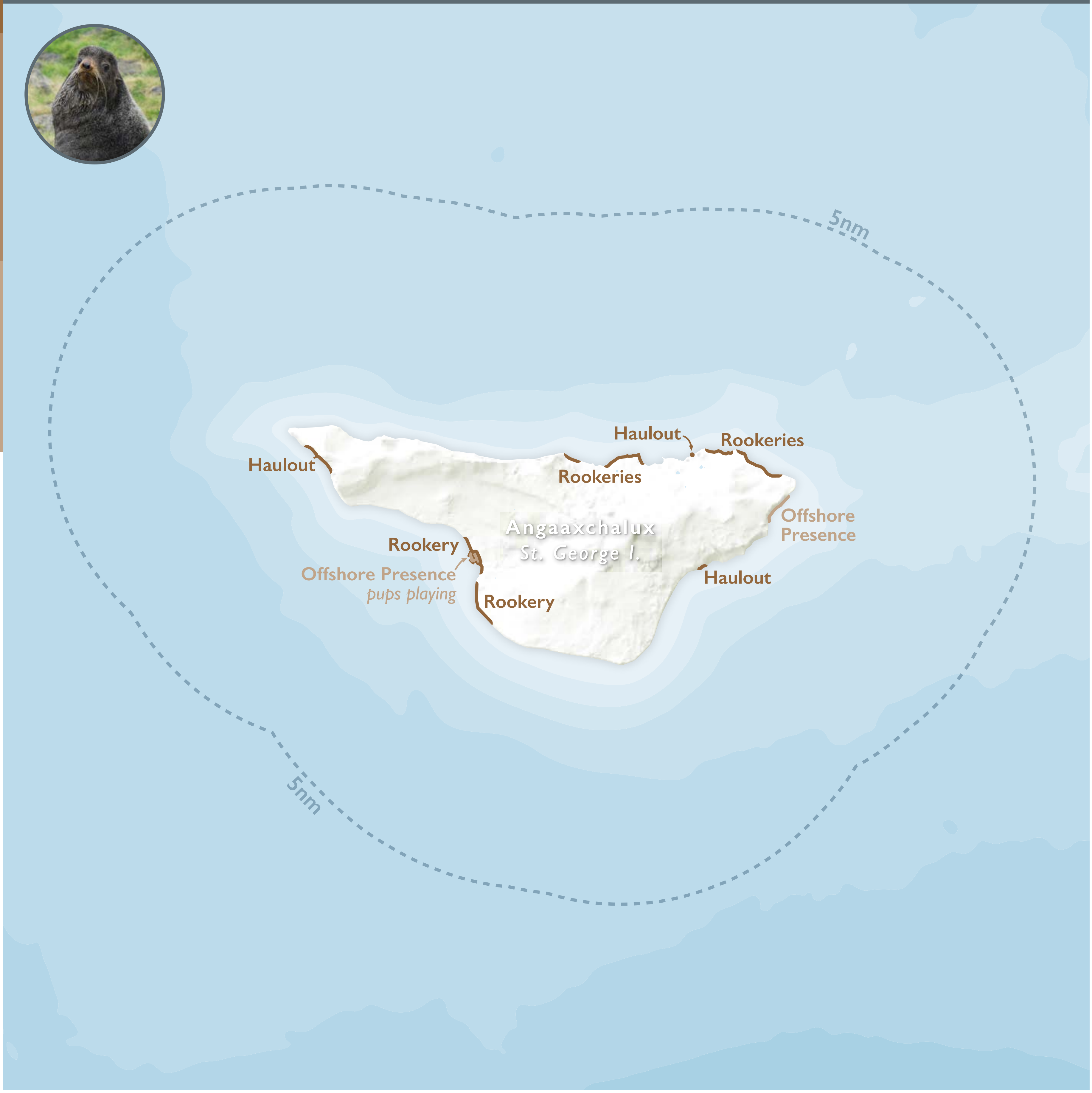
Northern Fur Seal

CITY of ST GEORGE
ALEUT COMMUNITY OF ST. PAUL TRIBAL GOVERNMENT
Audubon | ALASKA



ST. GEORGE 5NM

Northern Fur Seal



ST. PAUL 5NM

Northern Fur Seal

Steller Sea Lion

Qawan, or Steller sea lions (*Eumetopias jubatus*) have been an important cultural and subsistence resource for Unangan for millennia. The subsistence importance of *Qawan* to Unangan on St. George and St. Paul has been documented since the early 1800s (e.g., Veniaminov and Black 1984; Veltre and Veltre 1981) when *Qawan* were historically abundant in the Bering Sea and bred in large numbers on the Pribilof Islands. For more information on marine mammal subsistence around the Pribilof Islands, see the Subsistence Mammals of the Pribilof Islands section beginning on page 36.

Today, *Qawan* hunting predominantly occurs from September 1 to May 31 annually (Lestenkof et al . 2018). Hunting during the summer on St. George and St. Paul is almost non-existent due to *Laaqudan* (northern fur seal) rookery closures from June 1 to October 15 each year (50 CFR 216.81). Some hunting does occur during the summer in areas of the islands that are not occupied by *Laaqudan*, but these are rare occurrences.

Qawan gather on habitually-used rookeries on exposed, remote islands to give birth and breed. Dominant males defend individual territories on their rookery from mid-May through mid-July (Pitcher and Calkins 1981) and females mate with males who can hold the most preferred territory (Parker and Maniscalco 2014). Georg Steller observed that the males "hold the females in great respect," in contrast to northern fur seals that treat their females "harshly" (Steller 1899). During the breeding season, males typically do not leave their territory and will not eat for two months.

Females give birth to a single pup from mid-May through July, after 11.5 months of gestation (Pitcher and Calkins 1981). They breed shortly after giving birth on land, but the fertilized egg does not implant in the uterus and begin growing until October. Some females first breed at the age of 3, but by age 6, nearly all females produce pups. They generally return to their natal rookery to breed (Calkins et al. 1982), though some may disperse to a nearby rookery (Raum-Suryan et al. 2002). Males are able to breed at three to six years of age, but they must do so sneakily until they are older than nine, when they are large enough to compete for territories with dominant males (Pitcher and Calkins 1981).

Steller sea lions haul out on the shores of St. George Island, utilizing the area for foraging and resting.

J. Schoen

Qawan mothers nurse their pups for up to three years, and pups are weaned just prior to the next breeding season (Pitcher and Calkins 1981; Trites et al. 2006). Pups are left onshore for 7 to 62 hours while the mother forages at sea, depending on how long it takes her to find food (Hood and Ono 1997). A pup's early growth is key to its survival; *Qawan* milk is energy-rich and contains 20–30% fat and a variety of essential fatty acids (Higgins et al. 1988; Miller 2014). The pups are nursed at the rookery for 2 to 3 months before dispersing with the mothers to haul outs (Trites and Porter 2002). Pups as young as three months old can start catching their own fish to supplement their milk diet (Raum-Suryan et al. 2002).

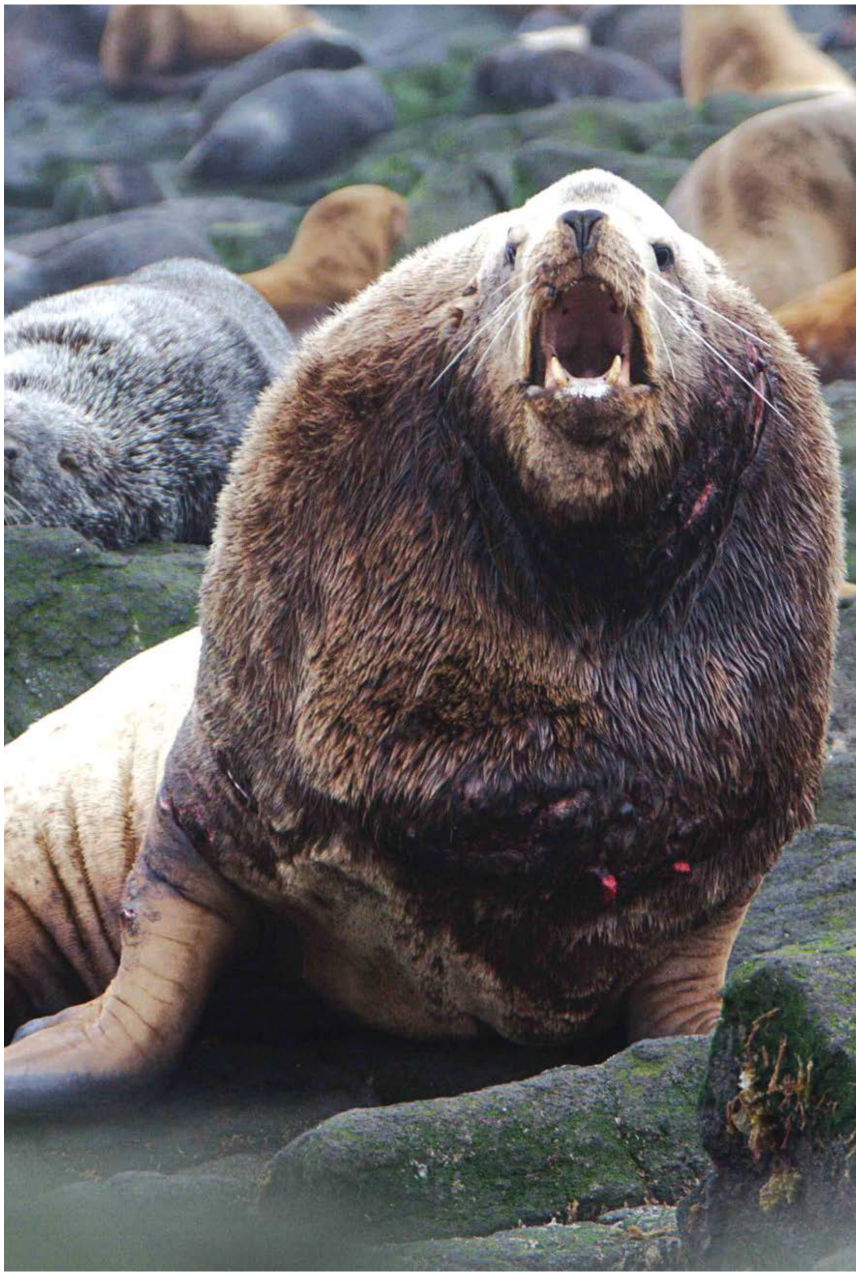
In winter, *Qawan* may move from their rookeries on the exposed coast to areas more protected from the weather or to the lee sides of islands. They can move over long distances, and adult males in particular may disperse widely after the breeding season (Jemison et al. 2013; Kenyon and Rice 1961). During fall and winter, many Steller sea lions disperse from rookeries and increase their use of haulouts, even hauling out on sea ice in the Bering Sea. They also gather at sea in protected bays and channels in a tightly packed group, or "rafts" near haulouts in winter.

Qawan eat a wide variety of fishes, such as walleye pollock (*Gadus chalcogrammus*), Atka mackerel (*Pleurogrammus monopterygius*), Pacific herring (*Clupea pallasii*), Pacific sand lance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), Pacific cod (*Gadus macrocephalus*), salmon (*Onchorhynchus* spp.), rockfish (*Sebastes* spp.), sculpins, flatfish, and invertebrates such as squid and octopus. Most of their top-ranked prey are off-bottom, schooling species. Feeding occurs from the intertidal zone to the continental shelf. They have regionally specific diets (Sinclair et al. 2005) and seem to remember when and where predictable concentrations of prey occur (Sigler et al. 2009). In the Gulf of Alaska, their diets include pollock, salmon, and arrowtooth flounder (*Atheresthes stomias*); in the western GOA and eastern Aleutian Islands their most important prey are pollock, salmon, Atka mackerel (*Pleurogrammus monopterygius*), sand lance, and herring; while those in the western Aleutians, including the Pribilof Islands, eat Atka mackerel, Pacific cod and cephalopods (Sinclair et al. 2005).

The population trend in the Pribilof Islands reflects the overall declining population trends of sea lions since the late 1970s; partially due to the perception that sea lions interfered with the management of the fur seal herd by competing for both food and space (Scheffer 1946). Elliott (1880) reported that approximately 10,000 to 12,000 animals were distributed at rookeries on both St. Paul and St. George Islands in the 1870s; but the breeding rookeries on St. George Island were extirpated by 1916 (Loughlin et al. 1984). The sole remaining recognized rookery in the Pribilof Islands is on Walrus Island, offshore of St. Paul Island.

"I started noticing sea lions declining in the 1980s after foreign boats had been fishing since the 1960s, and you know, it will be the same with the fur seals."

~ M. Merculieff Sr.



V. Burkanov / NOAA Fisheries Service

A bull sea lion vocalizes amongst resting fur seals and sea lions.

MAMMALS

STELLER SEA LION

150NM

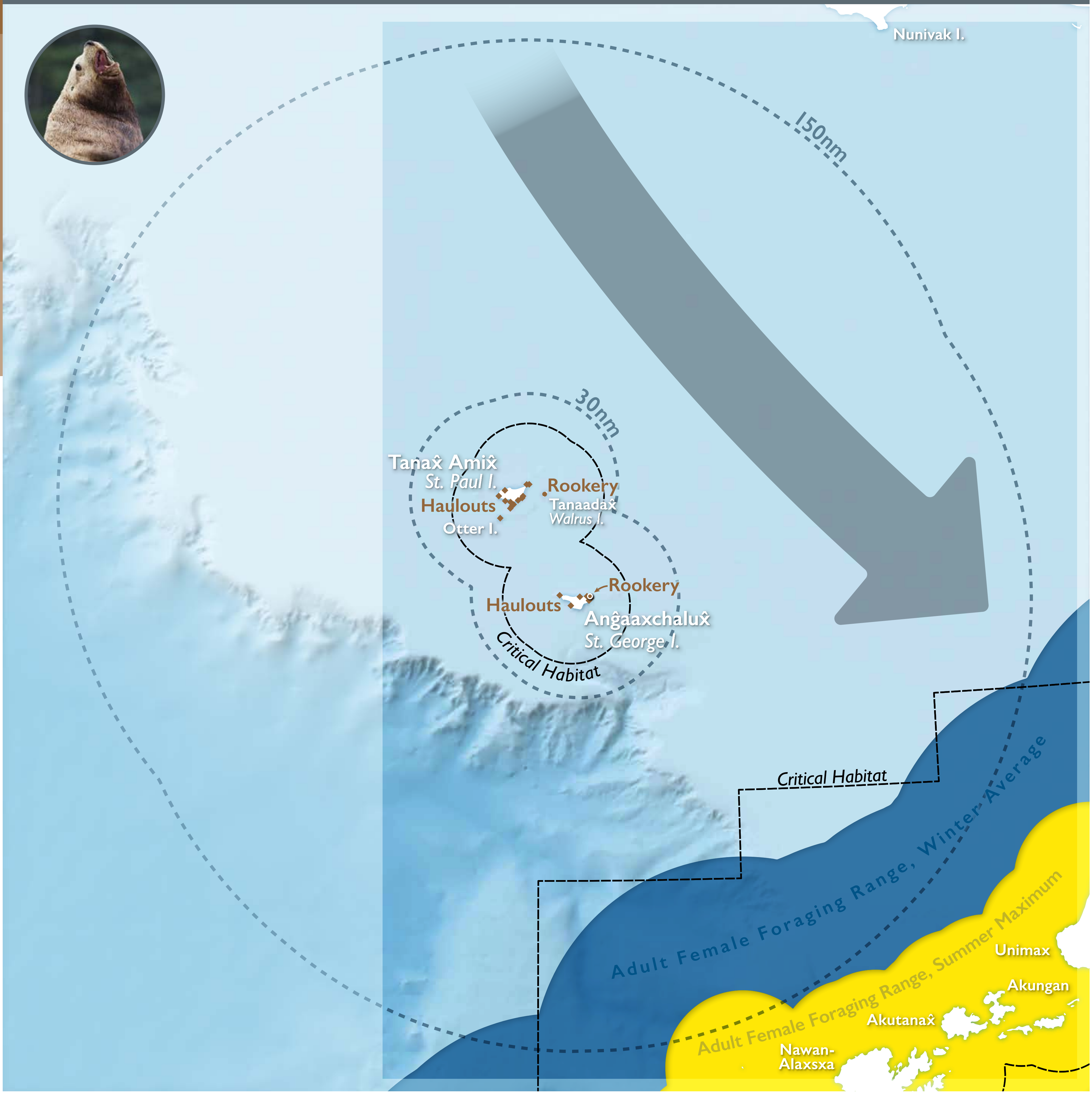
150NM

Steller Sea Lion

CITY of ST GEORGE

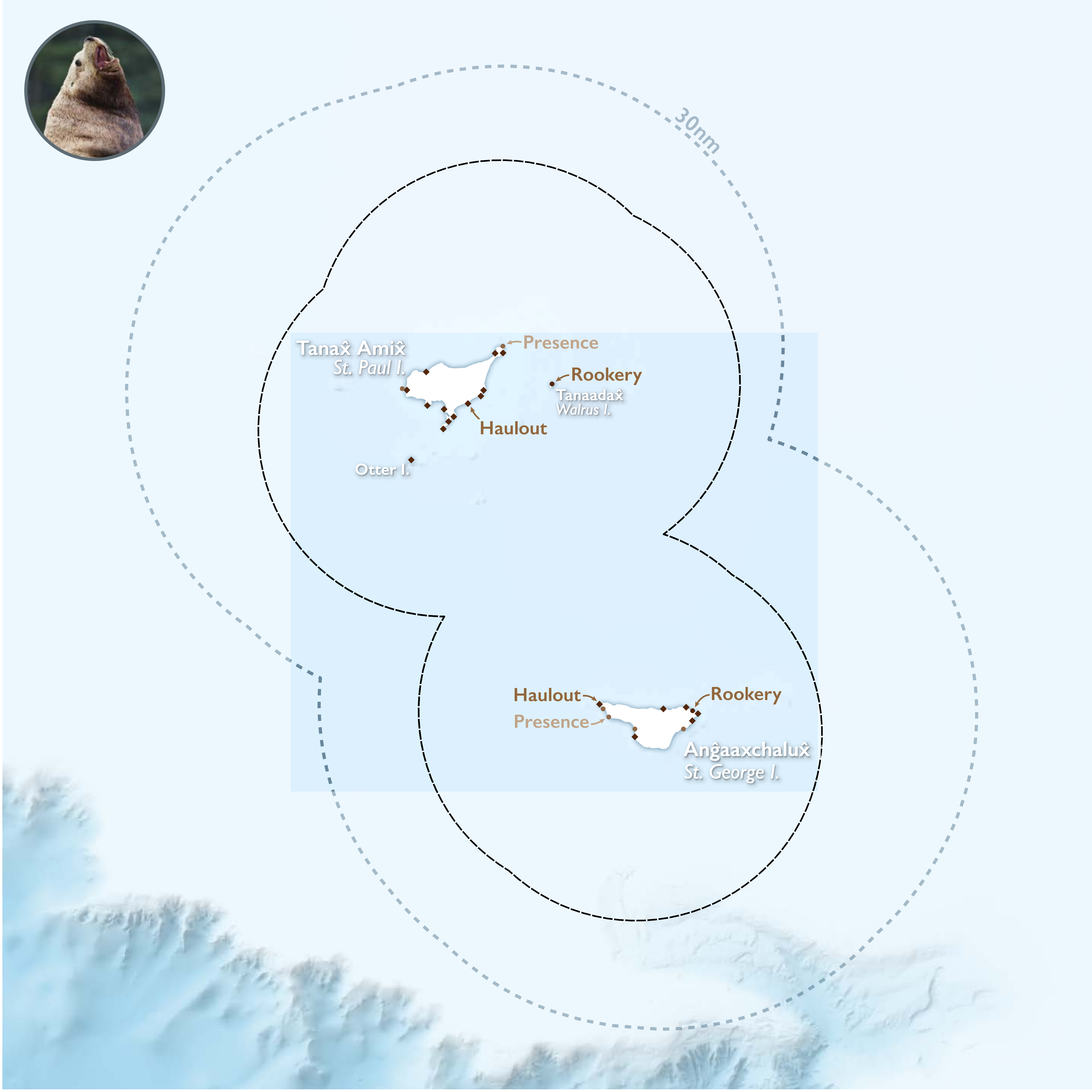
ALEUT COMMUNITY OF ST. PAUL TRIBAL GOVERNMENT

Audubon | ALASKA



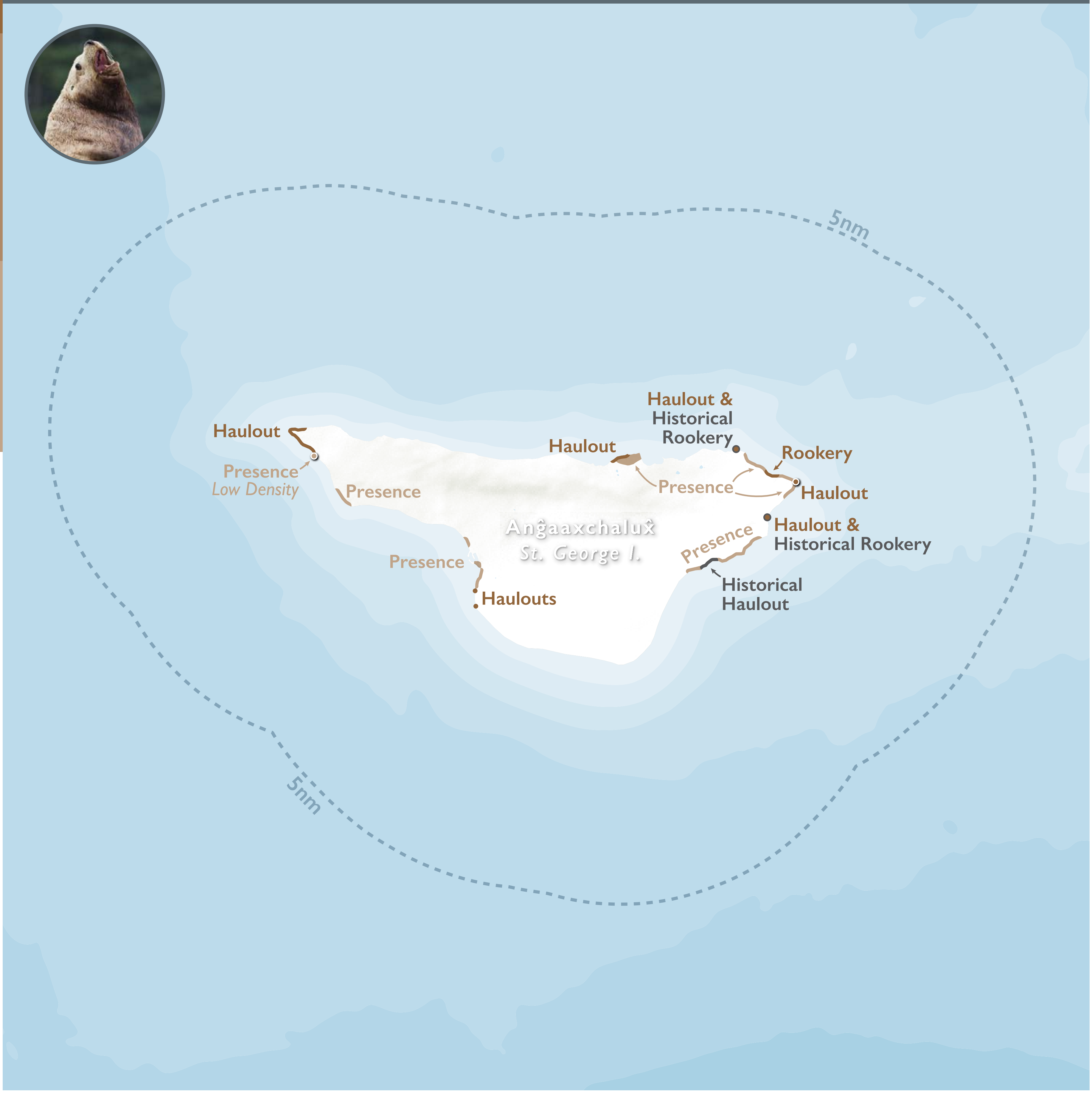
30NM

Steller Sea Lion



ST. GEORGE 5NM

Steller Sea Lion



ST. PAUL 5NM

Steller Sea Lion

City of St George · Aleut Community of St. Paul Tribal Government · Audubon | Alaska

Pacific Walrus

Amgaadan, or Pacific walruses (*Odobenus rosmarus*) are identified and managed as a single, unstructured, population (US Fish and Wildlife Service 2014). While *Amgaadan* used to be "exceedingly abundant in the vicinity of the shores in the wintertime," and hauled out on *Tanaadax̂*, Walrus Island, and the shores of Northeast Point on St. Paul Island (Hanna 2008:184), today they are rarely seen alive around the Pribilof Islands, likely due to changes in sea-ice dynamics in the Bering Sea. However, in June 2018 a juvenile walrus was observed resting on St. Paul; this was the first sighting of a live *Amgaadax̂* in 13 years.

Amgaadan mate primarily in January and February in the Bering Sea. Leks (gatherings of males for the purpose of competing for the attention of nearby females) are formed in the water alongside groups of females hauled out on sea ice. The competition to mate includes vocalizations and visual displays among the dominant males. When appropriate, a single female will join a male in the water to copulate (Fay et al. 1984).

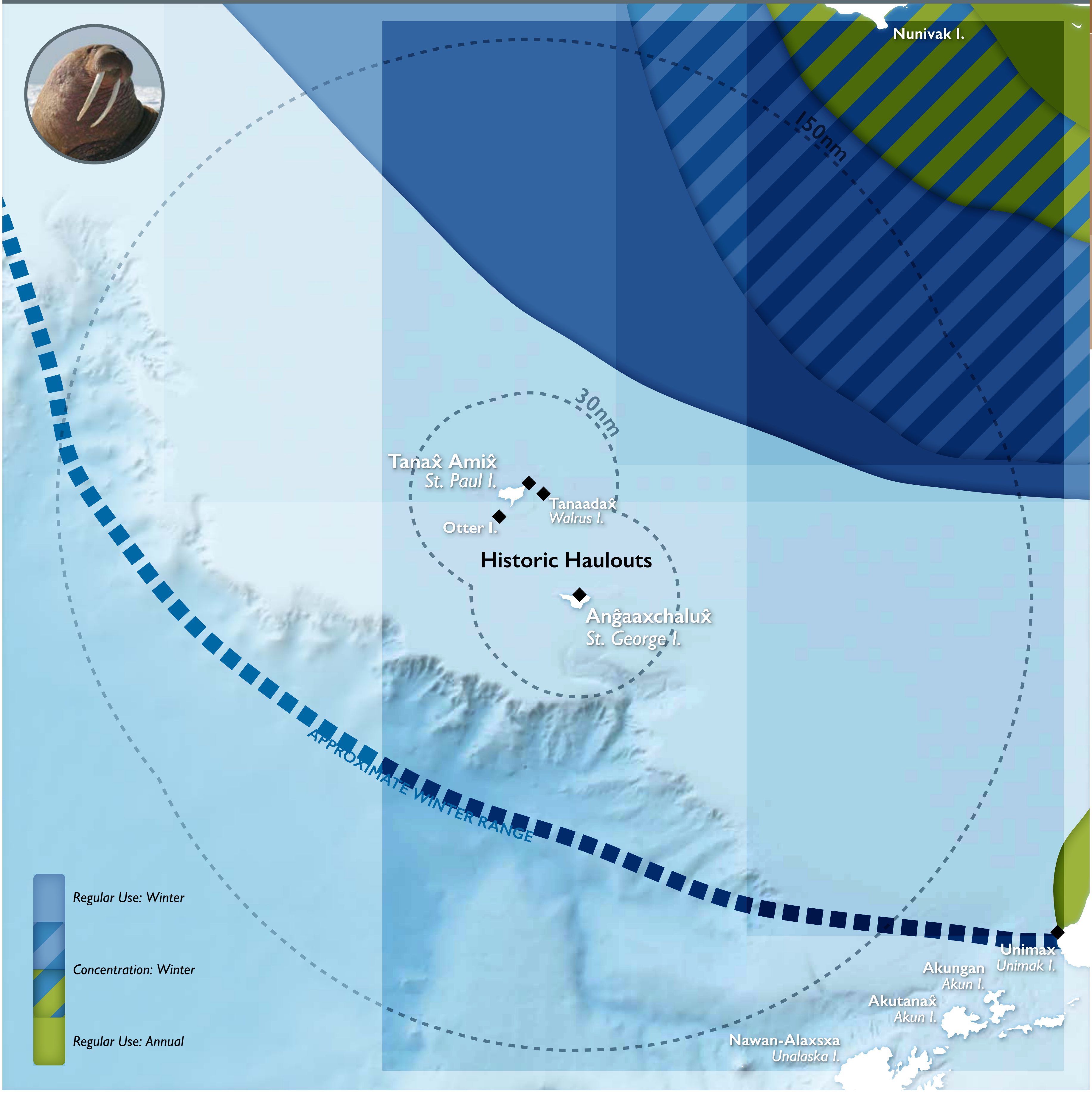
Amgaadan root with their muzzles in the bottom sediment of waters 300 feet (100 m) deep or less and use their whiskers to locate prey items (Fay and Burns 1988; Kovacs and Lydersen 2008). They use their fore-flippers, noses, and jets of water to extract prey buried up to 12 inches (30 cm) deep (Fay 1982; Kastelein 2009; Levermann et al. 2003). *Amgaadan* require approximately 60–180 pounds (25–70 kg) of food per day and utilize over 100 taxa as potential sources, although clams typically make up over 90% of stomach contents (Fay 1982). They typically swallow invertebrates without shells in their entirety (Fay 1982). They remove the soft parts of mollusks from their shells by suction and discard the shells (Fay 1982).

Walrus are very rarely seen in the Pribilof Islands today, and are most often observed dead stranded on the shorelines.

Adobe Stock

150NM

Pacific Walrus



M. Burcham

Birds

MAPS

AUKLETS

Bird Survey Effort

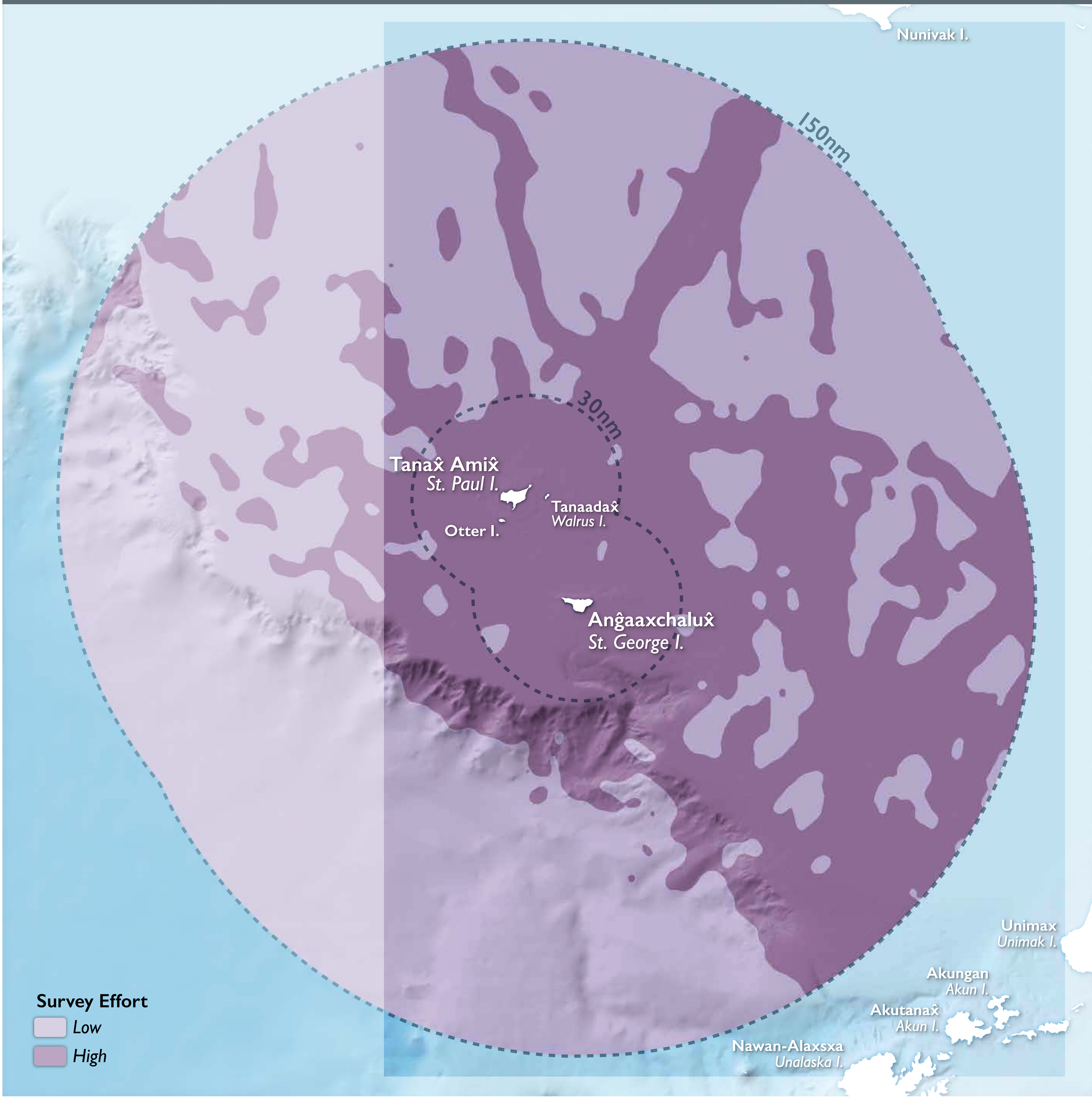
Audubon Alaska collected the available bird survey databases for this region and compiled them into a single dataset called the Alaska Geospatial Bird Database (AGBD) in order to seamlessly analyze bird distribution and concentration (Audubon Alaska 2016). The AGBD combines and integrates survey locations from available aerial and at-sea bird surveys conducted by the US Fish and Wildlife Service (USFWS), the National Park Service (NPS), and the Program for Regional and International Shorebird Monitoring (PRISM), as well as data from the North Pacific Pelagic Seabird Database (NPPSD) compiled by the US Geological Survey (USGS). Surveys included in the AGBD were conducted between 1973 and 2014. Bird survey effort (Audubon Alaska 2017) was calculated by counting the number of surveys within each 3.1 mile (5 km) cell. The AGBD survey data have variable coverage across the project area. The primary data source for at-sea observation data, the NPPSD, includes data from more than 350,000 transects designed to survey birds at sea, conducted over 37 years. Survey coverage and effort vary greatly, influencing overall accuracy of the resulting densities and mapped distribution patterns.

Island Sentinel A. Lestenkof walks the shorelines of St. Paul weekly on a Coastal Observation and Seabird Survey Team (COASST) walk.

H. Burgess, COASST

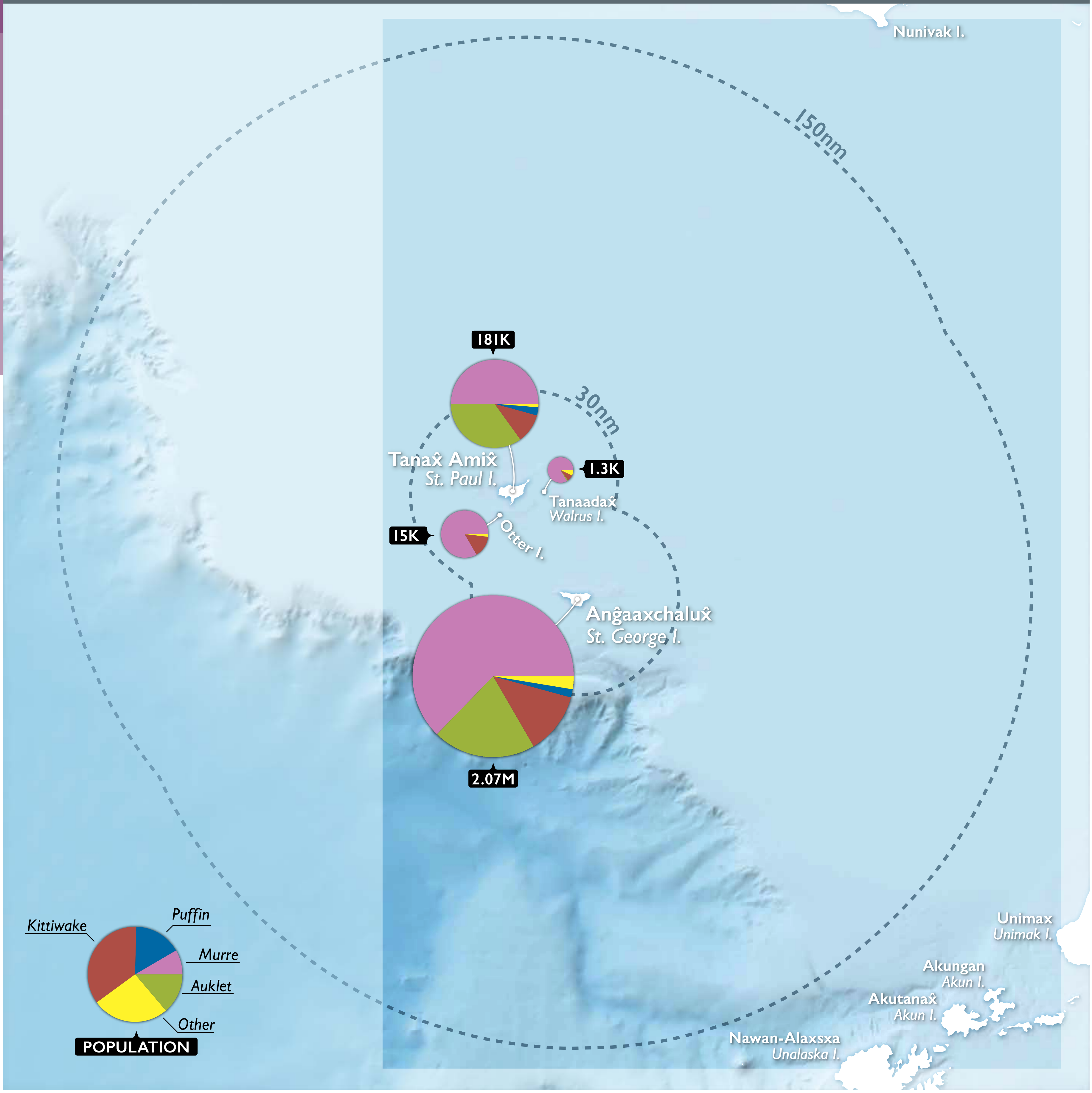
150NM

Bird Survey Effort



150NM

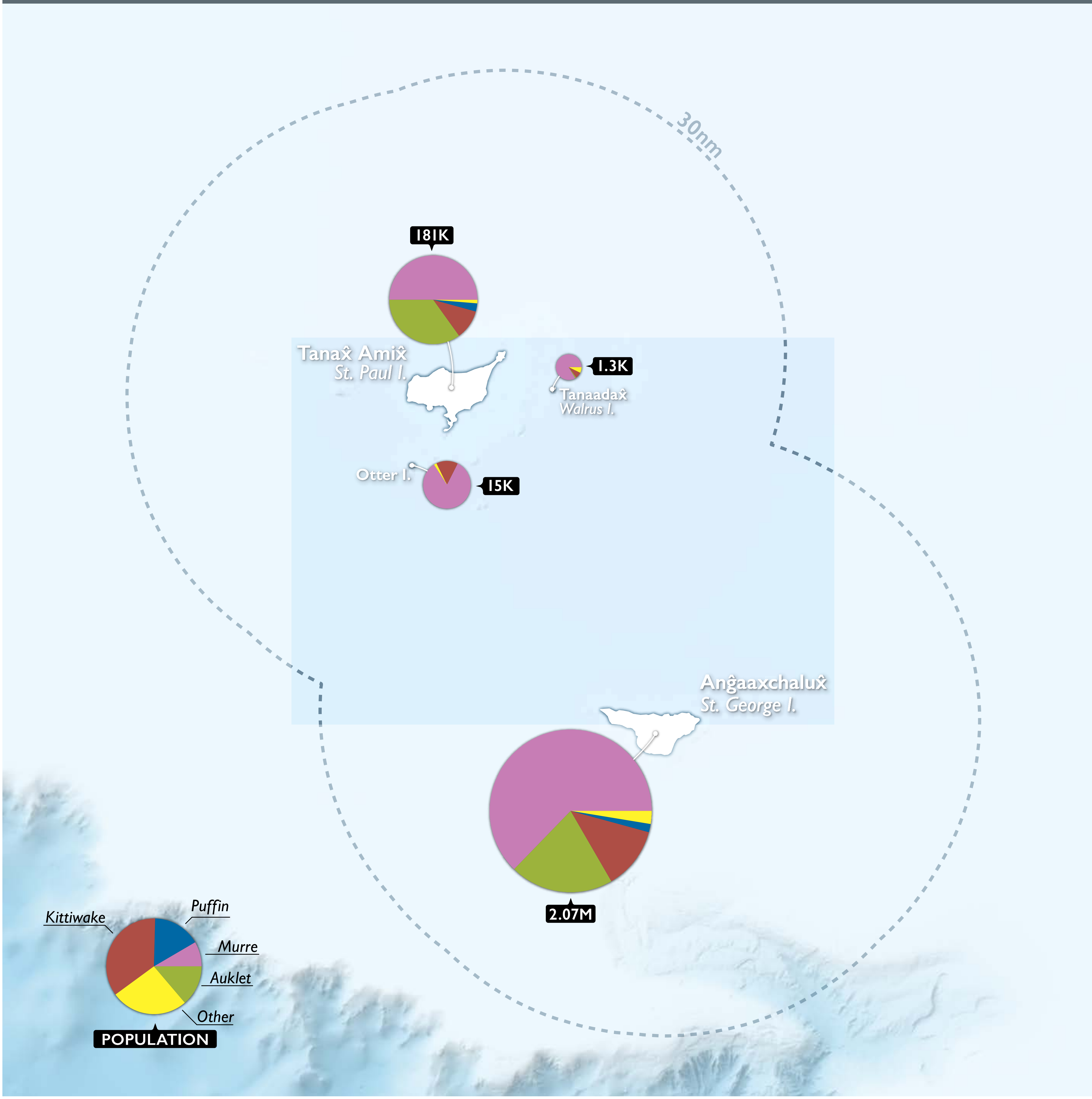
Seabird Colonies



30NM

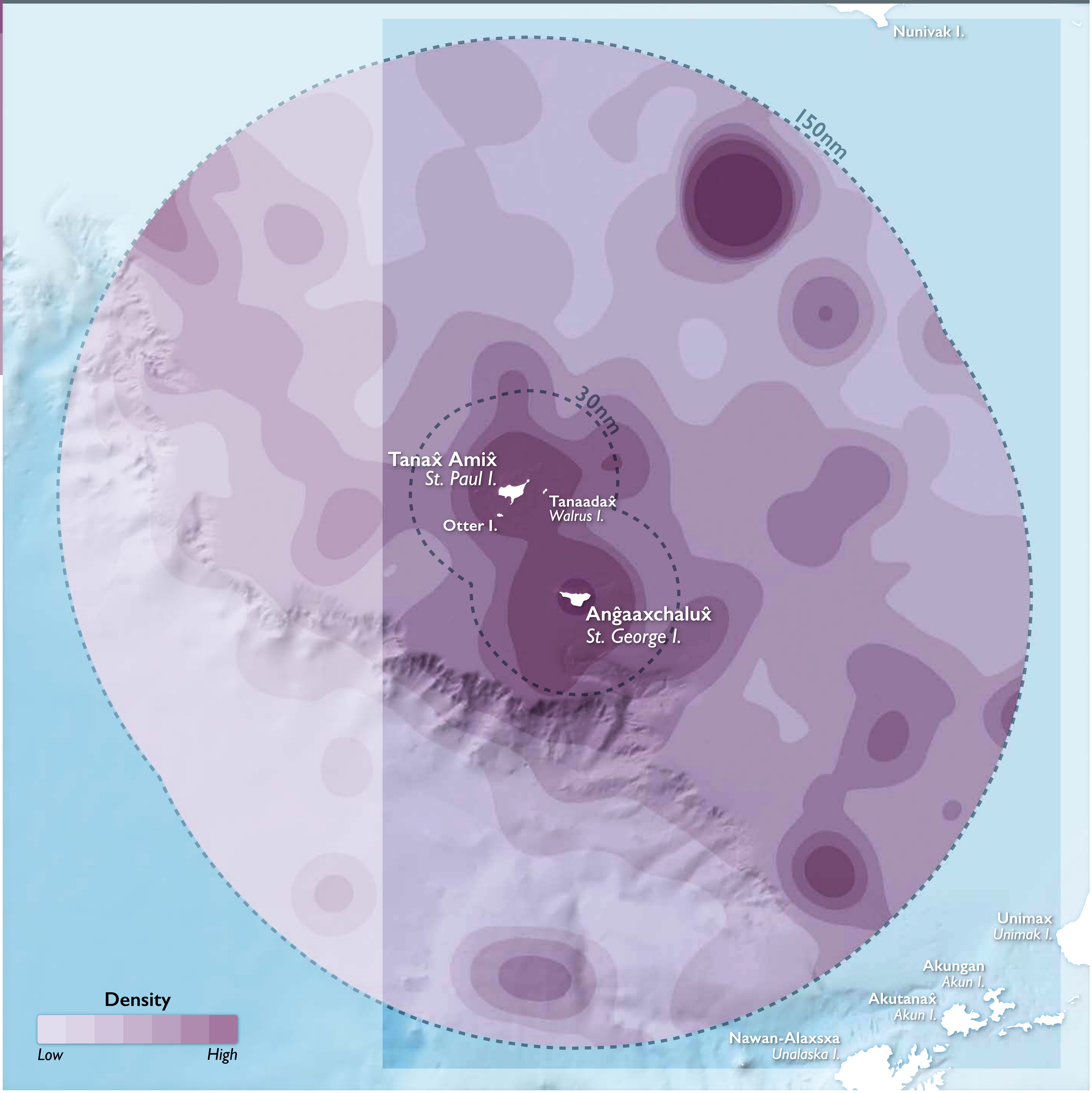
Seabird Colonies

CITY of ST GEORGE
ALEUT COMMUNITY OF ST. PAUL TRIBAL GOVERNMENT
Audubon | ALASKA



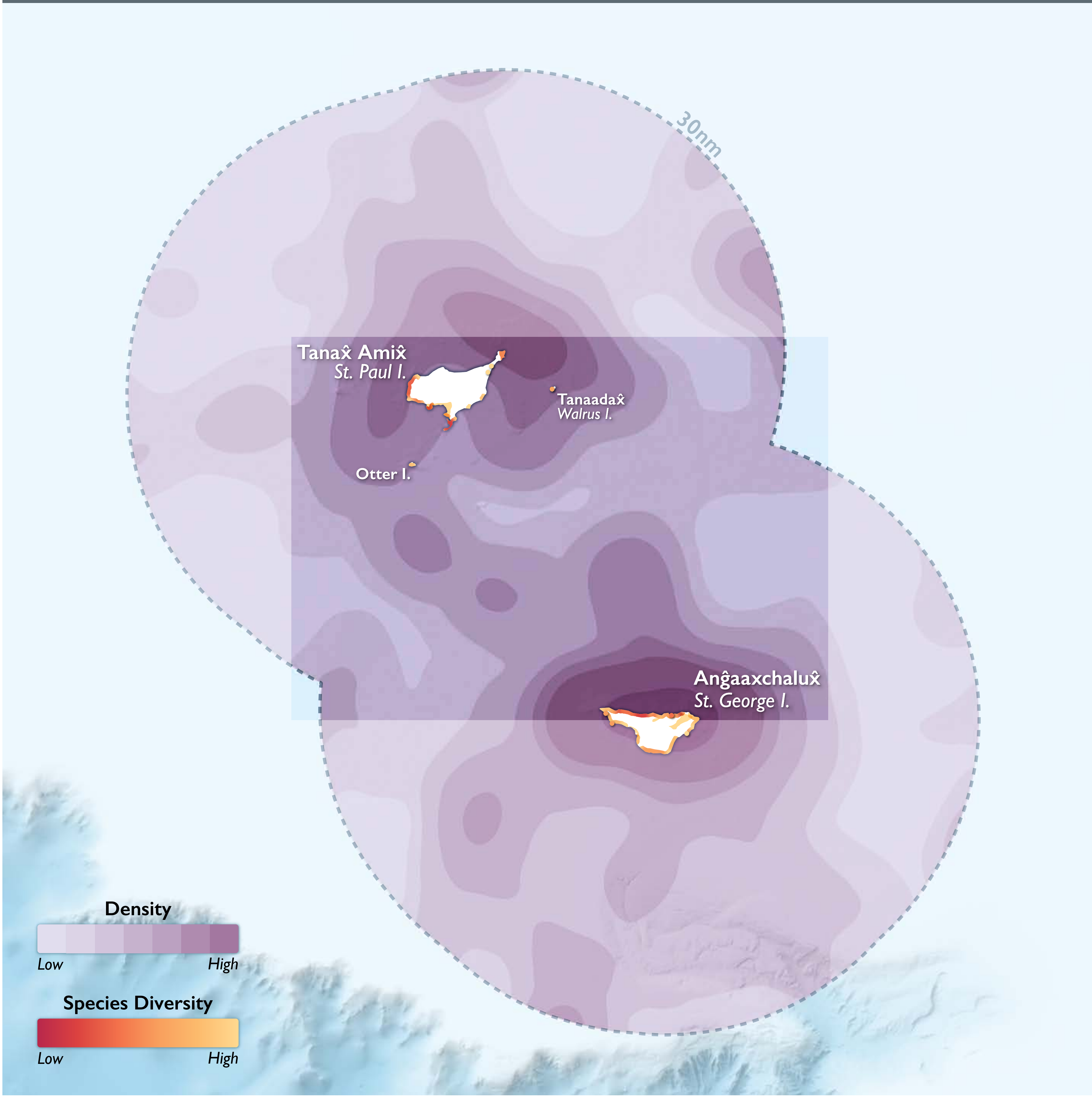
150NM

Colonial Seabirds



30NM

Colonial Seabirds



Subsistence Birds of the Pribilof Islands

In the Pribilof Islands, seabird harvesting and observations are an important part of family life and growing up. Generally, birds were stalked on the water surface and killed with a spear or arrow, or netted from blinds near rocky shorelines or on lakes, and birds were harvested from nesting sites by approaching cliffs by boat or being lowered on a rope from above (Veltre and Veltre 1982; Schroeder et al. 1987). Birds were caught at nesting and non-nesting sites using snares, bolas, handnets, clubs, leisters or by hand (Schroeder et al. 1987). Seabirds were harvested in a variety of ways for a multitude of uses, including as foods, for use in traditional regalia, and for other traditional and cultural uses. Species that were or are currently utilized for their eggs include: Common (*Sakitax̂*) and Thick-billed Murres (*Ulux̂txax̂*); Least Auklets (*Chuuchiiĝix̂*); Pelagic, Double-crested and Red-faced Cormorants (collectively *Anulgix̂*); and seagull (*Slukax̂*). Birds historically or currently utilized for meat include Least Auklets; Red-legged Kittiwakes; Pelagic, Double-crested and Red-faced Cormorants; Tufted (*Uxchux̂*) and Horned Puffins (*Qagidax̂*); and sea ducks (collectively called *San* meaning birds or ducks, which includes Spectacled, Common [*Kasimax̂*], and King Eiders [*Saakum Aliĝii*]; Harlequin ducks [*Kaangadgiix̂/Kaaxadgix̂*], White Winged Scoters, and Long tailed Ducks [*Aalngaaĝix̂*]).

Today the most common stories involving egging, or the collection of eggs from seabirds, involve *Sakitax̂* and *Ulux̂txax̂* (Common and Thick-billed Murre) and *Chuuchiiĝix̂* (Least Auklet). Children were allowed to accompany adults out of town to collect eggs, climbing over rocks to access crevices in the boulders where *Chuuchiiĝin* laid their eggs to reduce predation by Pribilof foxes (interview, 22 January 2019). Residents took egg cartons out for collecting and used the eggs frequently for cooking during June–July. On St. George, *Chuuchiiĝin* sometimes laid their eggs on still-present snow around Ulakaia Hill and could be spotted from some distance by the pinkish color characteristic of their guano (interview, 12 September 2018). Collection of *Chuuchiiĝin* eggs does not occur on the Pribilof Islands today as abundances are extremely low (St. Paul) or areas are not as accessible (St. George).

Another popular source for obtaining eggs is Murres (Common [*Sakitax̂*] and Thick-billed Murres [*Ulux̂txax̂*]). Historically, residents accessed Murre colonies by boat, approaching cliffs from the shoreline, or by climbing or being lowered down on ropes. About three decades ago, Elders on St. George requested younger generations “slow down or stop harvesting” Murre eggs due to observed declines (interview, 22 January 2019), and harvest continues to decline today, with little to no take on St. George and very low take on St. Paul.

> “Hunting is a dying culture…there are only 1 or 2 people younger than me who hunt. The price of shotgun shells are outrageous.”
>
> ~ D. Zacharof

Chuuchiiĝix̂ are the subject of many fond hunting memories for Elder residents of the Pribilof Islands. Residents remember harvesting *Chuuchiiĝix̂* as children and described harvesting as a good way to get children involved in subsistence activities and helping provide for the family (Young et al. 2014). *Chuuchiiĝix̂* hunting occurs by striking birds from the air with broom handles, bamboo, or other long, flexible driftwood that could be collected from the shorelines. Elders also report using a net made from a forked piece of driftwood and old fishing net or fashioning a slingshot type apparatus to bring in auklets. Residents describe waking up early in the morning (5 am) as children and walking to the rocky shoreline unsupervised where “all these auklets; thousands would come flying down from Ulakaia” (interview, 9 Sep 2018) where individuals could simply, “Swing a stick up and you could get five” (interview, 22 Jan 2019). However, subsistence hunting has declined on both islands in recent decades as the breeding auklet population has declined dramatically. In St. Paul, the decline of auklets has been especially concerning for residents, who fondly remember the familiar sounds of *Chuuchiiĝix̂* that traditionally indicated summer was coming. Tribal members lament the loss of *Chuuchiiĝix̂* calls and songs that were ever-present in their youth. Today, traditional *Chuuchiiĝix̂* hunting with sticks occurs only in the spring with youth as part of a cultural program to preserve traditional knowledge. Least Auklets remain more abundant on St. George, but residents understand that habitat decline is an important contributing factor to declining abundance over time; one elder noted that habitat loss due to increased vegetation growth in a warming climate has reduced access to rocky habitat where auklets typically nest.

Qaĝayaax̂, or Red-legged Kittiwakes, are a favorite among Elders on both islands, who often request breast meat collected by younger generations of hunters. *Qaĝayaax̂* are hunted using shotguns and processed in the field, and the meat is typically prepared as a traditional soup or stew. Consuming kittiwake soup reminds Elders of their childhood and instills

V. Padula

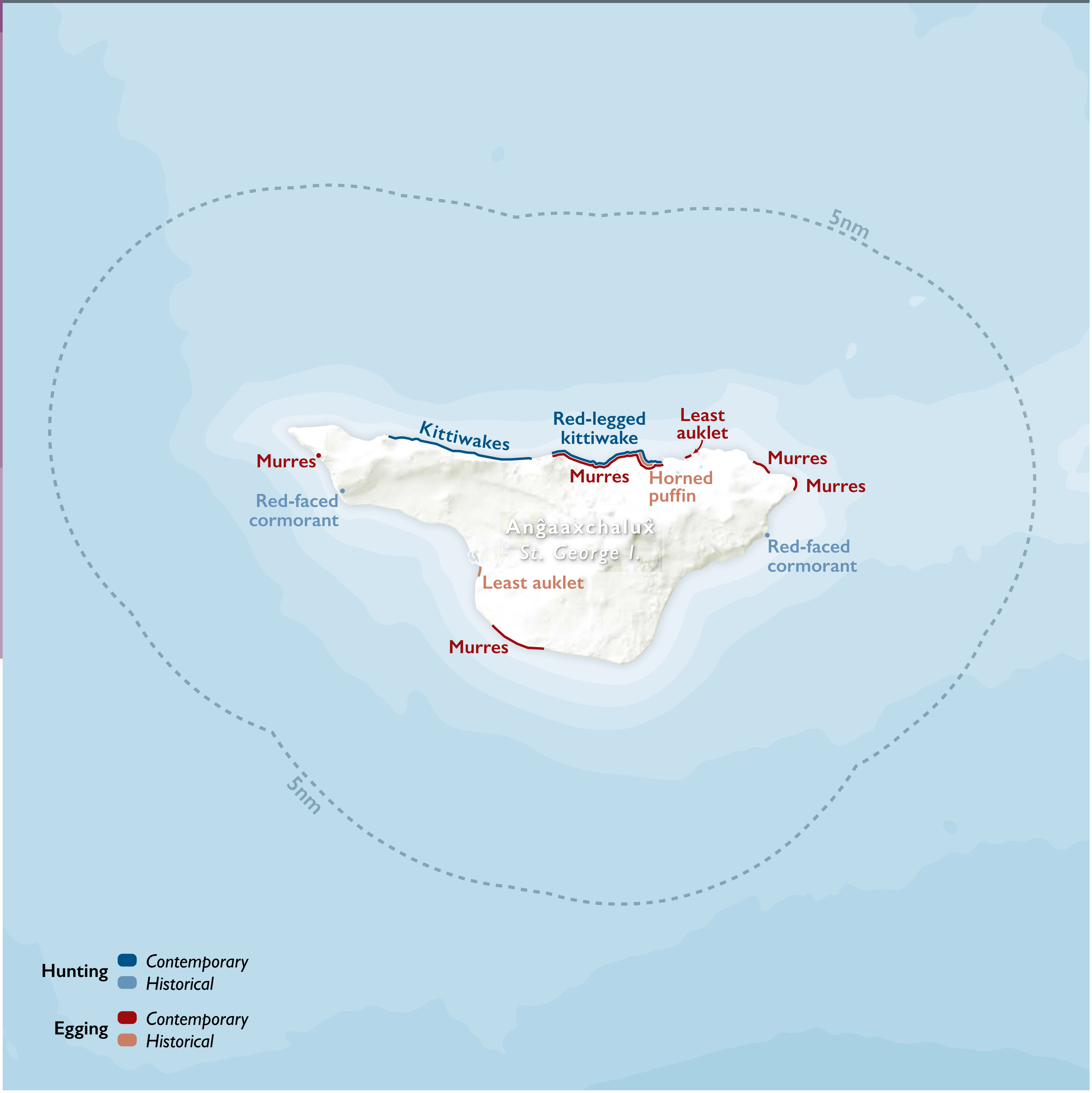
Murre eggs are streaked and dotted in patterns unique to each egg; no two eggs are the same.

a connection with their ancestors, contributing much to individual health and well-being beyond the biophysical benefits of nutrition. However, younger generations tend to consume very little *Qaĝayaax̂*, at least partially as a response to alarming declines in *Qaĝayaax̂* abundance in the Pribilofs, the availability of other subsistence and non-subsistence foods, and changing taste preferences. *Qaĝayaax̂* hunting has declined dramatically in recent decades due to an aging population of hunters, with over 80% of self-described subsistence hunters over 46 years of age, with 43% being over the age of 60 (Young et al. 2014). Traditionally, *Qaĝayaax̂* were hunted from March until May, and then again in late September on both islands (Osgood et al. 1915:123; Veltre and Veltre 1981). Today hunting primarily occurs in the spring on St. George and in the fall on St. Paul.

Sea ducks (Spectacled, Common, and King Eiders; Harlequin ducks; White Winged Scoters; and Long-tail ducks) have also been a staple of winter and spring Unangan diets, as they were available before *Laaqudan* (northern fur seals) returned to the islands annually. Joining an adult seabird hunt was described as a rite of passage, with one resident remembering fondly the gift of "a ten-gauge at ten" so that he could help his father hunt sea ducks and kittiwakes (Young et al. 2014). Sea duck hunting occurred with shotguns and included all species that were available during the fall and winter seasons, including geese, ducks, and eiders. Today, hunting is still a popular subsistence activity at several locations on St. Paul, with less sea duck use on St. George. St. Paul also draws commercial or sport duck hunting outfitters that provide hunting opportunities for eiders and duck species.

ST. GEORGE 5NM

Subsistence Birds



ST. PAUL 5NM

Subsistence Birds

Red-faced Cormorant

Anulgix̂ (Red-faced Cormorant, *[Phalacrocorax urile]*, also known as *Aagyuuĝiigamax̂*, *Ingatux̂*, and *Aagyuux̂*) occur in a latitudinally narrow band from the Kenai Peninsula west through the Aleutian Islands, Alaska; the Commander Islands to the Kuril Islands and the Kamchatka Peninsula, Russia; and in northern Japan. *Anulgix̂* are not migratory; instead, they may disperse within nearshore areas of their year-round range after breeding. As their name suggests, *Anulgix̂* are distinguished by the red facial skin that is prominent in breeding adults. It is often paired with a yellowish bill and a pale blue gape. Also, while in breeding plumage, adult birds display a single crest of feathers on their crown, or sometimes double crests on their crown and nape, and a conspicuous white patch on their flank (Causey 2002). They are, in general, approximately 25% larger than *Aagyuuĝim kahnuliisxii* (Pelagic Cormorants; *Phalacrocorax pelagicus*), which also occur in the Pribilof Islands. They have a well-developed uropygial gland, an oil gland which they use to oil their wet feathers by first rubbing it with their bill, and then preening their feathers, in order to reduce saturation on subsequent dives.

Anulgix̂ are known as one of the trademark species of the Pribilof Islands, with breeding often being successful even when other seabird species have low productivity success. They are among the first to arrive at nesting sites on St. George and St. Paul and defend their preferred locations, which are comprised of the least accessible portion of the seaside cliffs (Nysewander 1983). Pair bonding occurs in early to mid-May, and after breeding birds have found a mate, the males initiate the process of building a trial nest to strengthen their bond in a location that the male will often use year after year. The trial nest is rarely used for incubation (Wright et al. 2013).

Anulgix̂ lay 2–4 greenish to pale-blue eggs, each 2–2.5 inches (6–6.5 cm) long and covered in chalky white deposits. The female cormorant lays an egg every two days (Wehle 1978; Hunt et al. 1981; Nysewander 1983; Wright et al. 2013). The clutch will never be left alone, as there are often egg-eating predatory birds such as Glaucous-winged Gulls (*Larus glaucescens*) and the Pribilof fox (*Alopex lagopus pribilofensis*) in the vicinity of the nesting sites (Hunt et al. 1981; Nysewander 1983; Wright et al. 2013). Chicks hatch featherless, with their eyes closed. Red-faced Cormorant breeding pairs share brooding duties, never leaving the nestlings alone for the first 4 weeks of life (Palmer 1962; 1976). As is the case with many seabirds, the survival rate of the brood is approximately 50%, and they are not known to produce a second clutch even when the first is completely lost (Hunt et al. 1981; Wright et al. 2013). After 40–50 days, the chicks will fledge, but will continue to obtain food from their parents for several weeks (Robertson 1971; Wright et al. 2013).

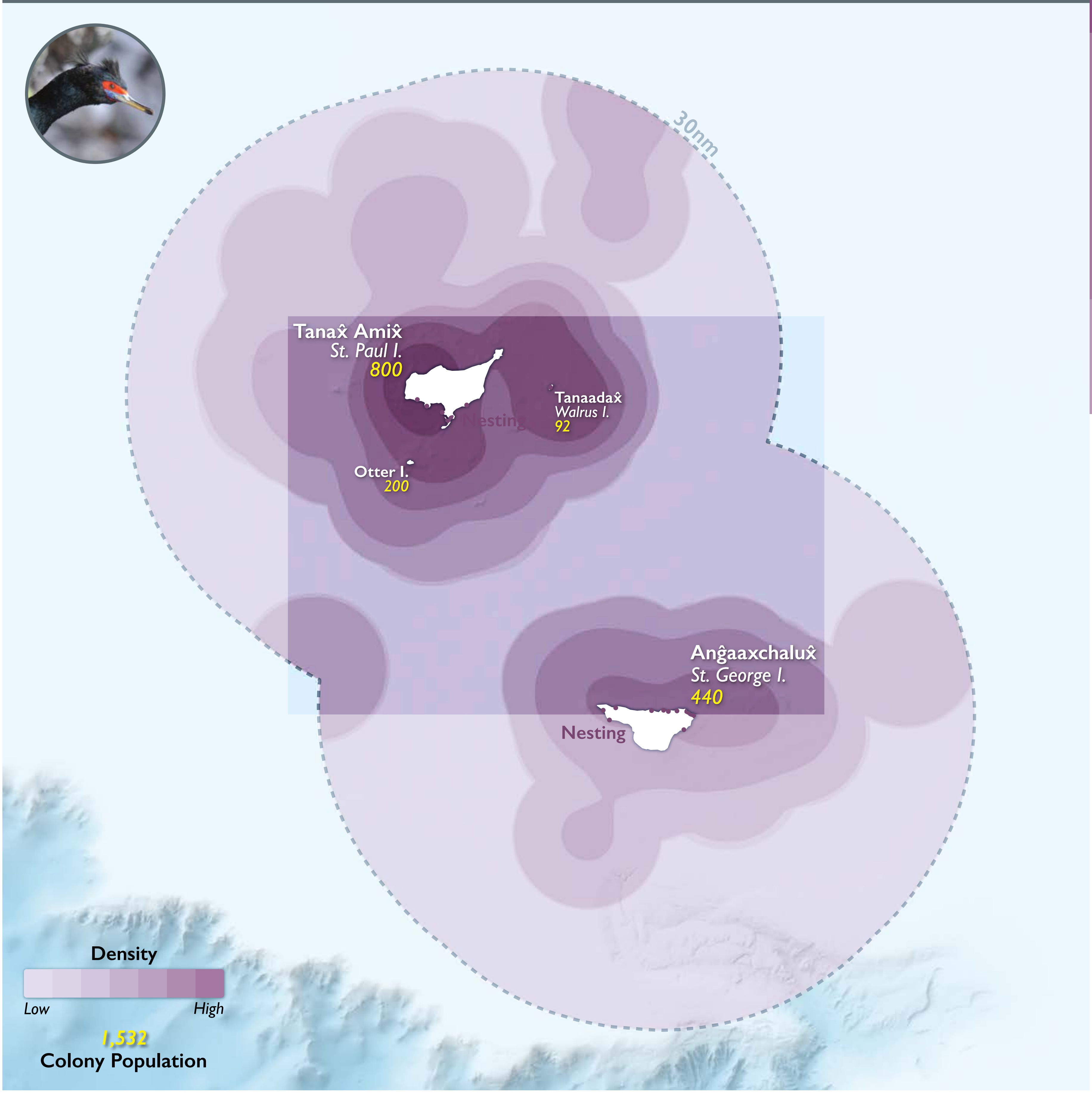
Anulgix̂ feed on fishes that live on the ocean floor such as smelt, sand lances, flounder, and sculpin, as well as some bottom-dwelling macro-invertebrates, including amphipods, euphausiids, decapods, polychaete worms, and pelagic mollusks (Palmer 1962; Hunt et al. 1981). They generally hunt in inshore areas with rocky bottoms, pursuing their prey by diving from the water's surface, propelling themselves with their feet, and swallowing their prey underwater, except when it is large or difficult to swallow (Hoffman et al. 1981; Causey 2002).

A. Filardo / UAF CFOS

A banded Red-faced Cormorant finds a sunny rock to rest on.

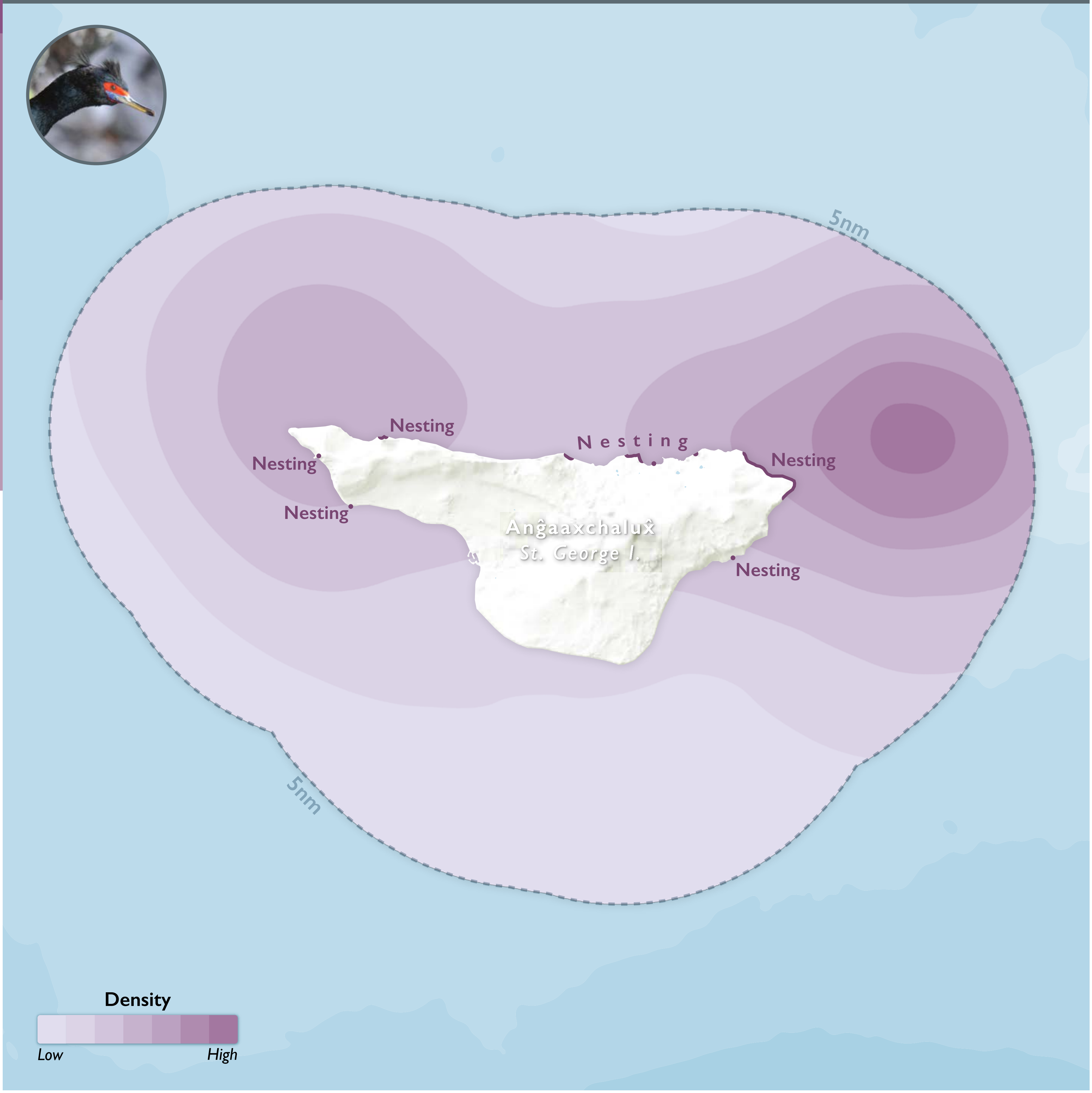
30NM

Red-faced Cormorant



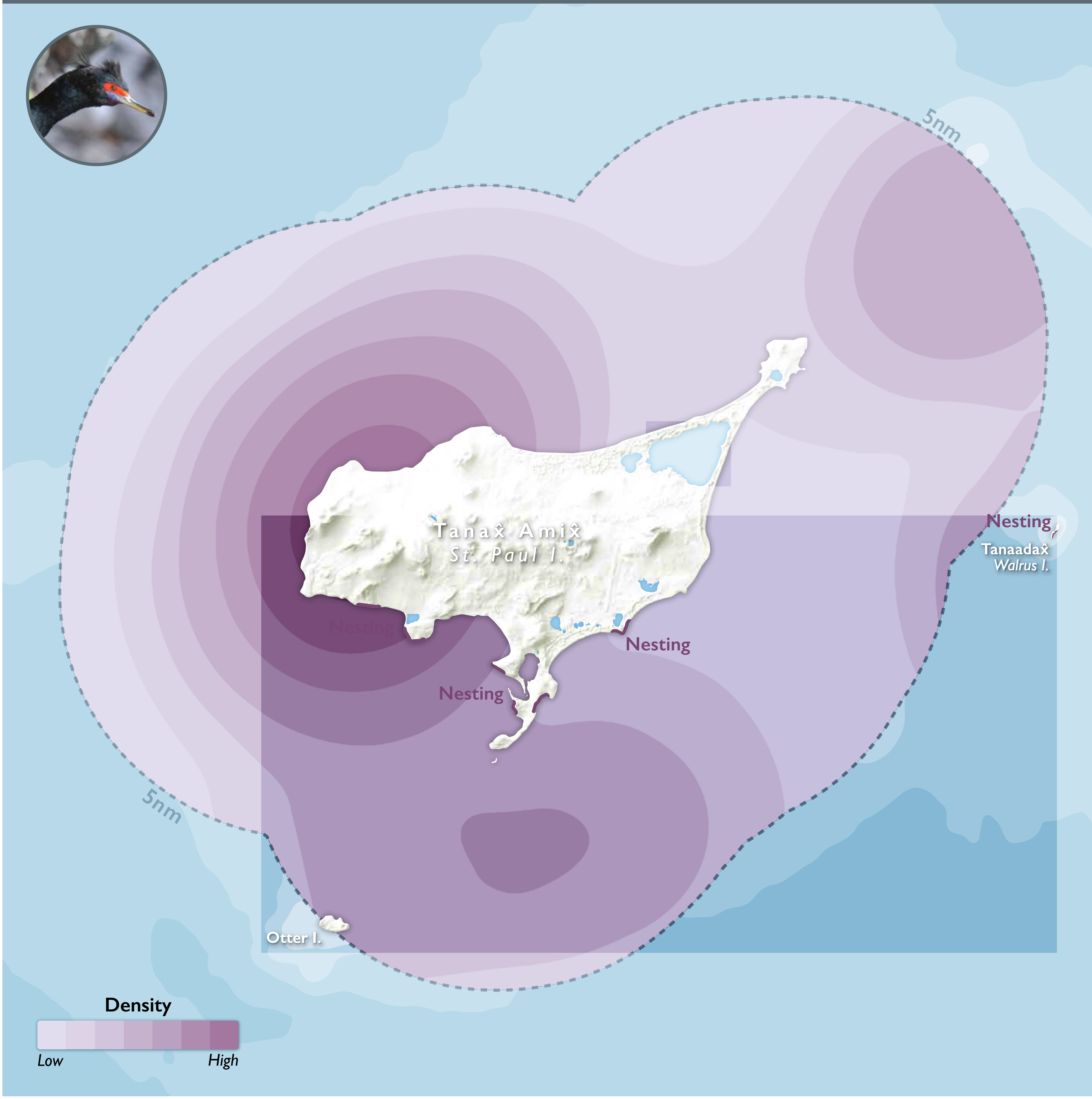
ST. GEORGE 5NM

Red-faced Cormorant



ST. PAUL 5NM

Red-faced Cormorant



Kittiwakes

Qaĝayaax̂ (Red-legged Kittiwake; *Rissa brevirostris*) and *Gidaaĝix̂/Qaĝayax̂* (Black-legged Kittiwake; *R. tridactyla*) are small gulls with forked tails and mostly white plumage, accented by a gray back (darker in *Qaĝayaax̂*) and black-tipped wings. A kittiwake's bill is relatively small, thin, and greenish-yellow in color. *Gidaaĝix̂/Qaĝayax̂* has a longer, more pointed bill than its sister species. Differences in bills and profiles, as well as the namesake differences in leg color, are evident field marks to differentiate between species (Kaufman 1989). The legs of *Qaĝayaan* are scarlet red and distinct. Their short legs and dexterous claws are well suited for nesting on the tenuous substrate of coastal cliffs, yet these same features encumber their ability to walk with agility. They are excellent fliers and can hover on the wing, easily making difficult maneuvers in and out of their precarious nests.

Kittiwakes form large, dense, noisy colonies upon coastal cliffs, often within 25 miles (40 km) of productive feeding grounds (Biderman and Drury 1978; Hunt et al. 1981; Springer 1991). Kittiwakes are known to travel great distances for food. They prefer nest sites on near-vertical faces up to 1,000 feet (300 m) high, often among murres or other cliff-nesting seabirds (Hickey and Craighead 1977; Hunt et al. 1981). In June, the female lays a single egg, rarely laying a second (Hunt et al. 1981; Johnson and Baker 1985; Lloyd 1985; Byrd 1989). Both parents participate in incubation and foraging during the approximately four weeks between laying and hatching (Hunt et al. 1981). After hatching, the young stay in the nest for the first two weeks before venturing out to explore the area directly surrounding the nest. They fledge after about five weeks and will return to the nest for food for several weeks (Hunt et al. 1981). Kittiwakes feed within the top few feet of the ocean surface (Hunt et al. 1981; Hatch et al. 1993), traveling up to 60 miles (200 km) in the Pribilof Islands to forage (Kokubun et al. 2015). They are especially buoyant, and are not well adapted to diving, so they forage by pursuit-plunging or dipping after their prey, seeking small fish and marine invertebrates such as sand lance (*Ammodytidae* spp.), capelin (*Mallotus villosus*), Pacific herring (*Clupea pallasii*), Arctic cod (*Arctogadus glacialis*), saffron cod (*Eleginus gracilis*), lanternfishes (Myctophidae), northern lampfish (*Stenobrachius leucopsarus*), walleye pollock (*Gadus chalcogramma*), squid (cephalopods), amphipods, and euphausiids (Schneider and Hunt 1984; Bradstreet 1985; Dragoo 1991). Both species of kittiwake are often seen foraging over large schools of fish among larger gulls, murres, terns, cormorants, and puffins.

The global population of 300,000 *Qaĝayaan* nests only on coastal cliffs in a few small colonies in the southeastern Bering Sea. The islands supporting *Qaĝayaax̂* colonies include the Pribilofs, Bogoslof, Fire and Buldir islands in Alaska; and Bering, Cooper and Arri Kamen Islands in the Commander Islands, Russia (Stejneger 1885; Preble and McAtee 1923; Kenyon and Phillips 1965; Byrd and Tobish 1978; Firsova 1978). 80% of the world's population of *Qaĝayaax̂* nest on the coastal cliffs of the Pribilof Islands, with 75% nesting on St. George alone (Byrd and Williams 1993). They range from the Gulf of Alaska north through the Bering Sea to the Chukchi Sea, west as far as mainland Chukotka, south as far as Japan, and east to Prince William Sound. *Qaĝayaan*, known as one of the more cherished seabird species occurring in the Pribilof Islands, are an important subsistence resource, mainly due to the large portion of the overall population that breeds on St. George and St. Paul.

Gidaaĝix̂/Qaĝayax̂ are distributed across circumpolar coastal areas of the Arctic and subarctic. In Alaska, they nest as far north as Cape Lisburne and as far south as Boussole Head near Glacier Bay, with the largest portion of the population breeding in the Gulf of Alaska (Fairchild et al. 2007; Seabird Information Network 2017). The Pribilof Islands support 70,000-130,000 breeding *Gidaaĝin/Qaĝayan*. Pacific breeding birds travel as far west as the Kolyma River Delta in Russia and are known to utilize Wrangel Island south to the Sea of Okhotsk (Kondratyev et al. 2000). Black-legged Kittiwakes are also used as a subsistence resource, though less so than Red-legged Kittiwakes, and rarely in the Pribilof Islands.

"Off in the distance the kittiwakes come in flocks—the majority of them are black-legged kittiwakes—and you can tell from years of doing this; you look for a quicker flap in the wings, they flap just slightly faster [than black-legged kittiwakes], and their wings are arched ever so slightly. I don't know exactly how to describe this. They are actually darker in color underneath the wing as they approach and that's what I look for in a bird."

~ P. Melovidov, talking about how he identifies Red-legged Kittiwakes while hunting

M. Thompson

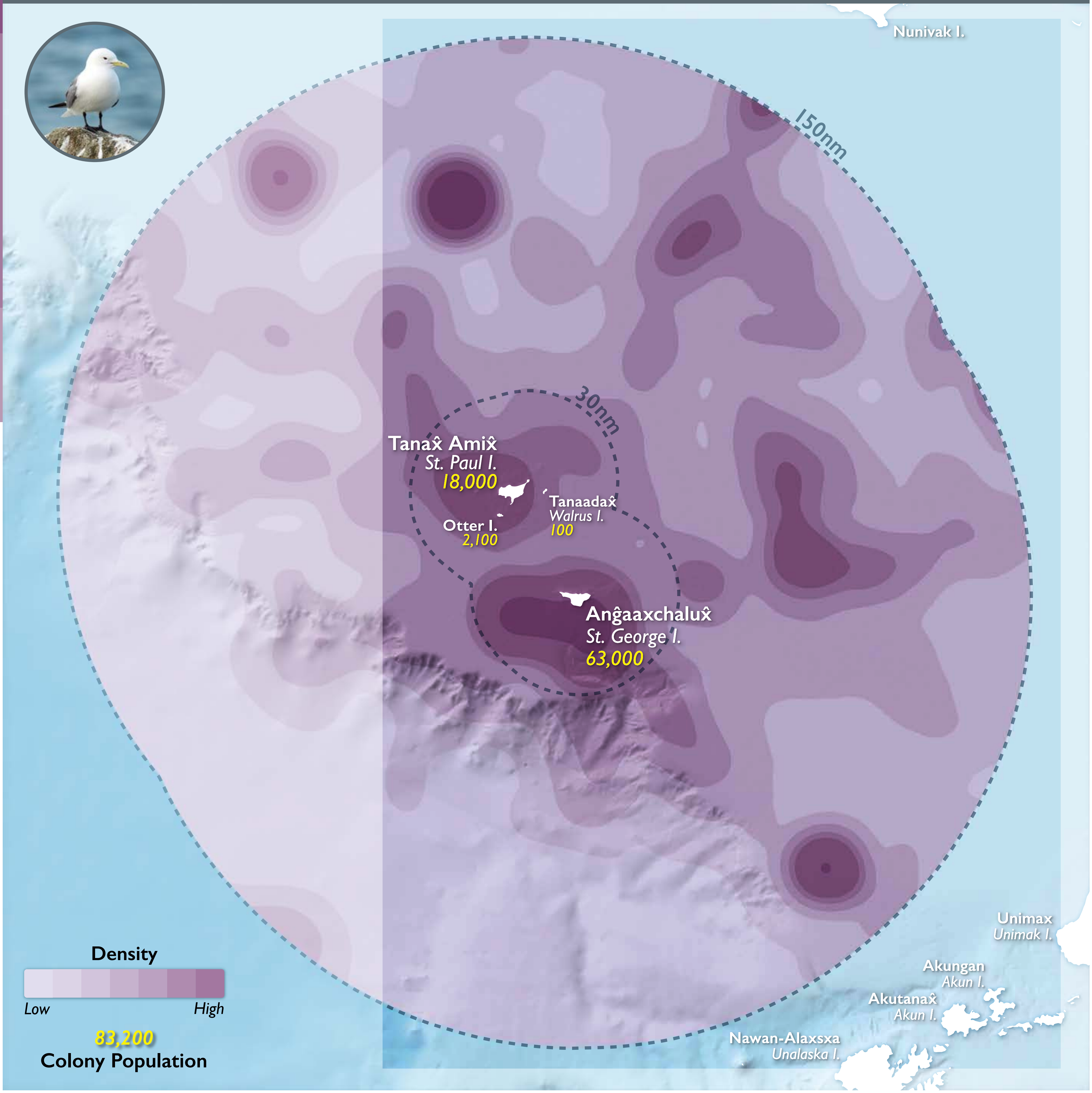
Black-legged Kittiwakes are broadly distributed across Alaska and the Arctic and are a critical sentinel species to indicate marine ecosystem health.

M. Burcham

Red-legged Kittiwakes are rare in comparison to their sister species, the black-legged kittiwake. A majority of the world's breeding population of Red-legged Kittiwakes nests on St. George Island.

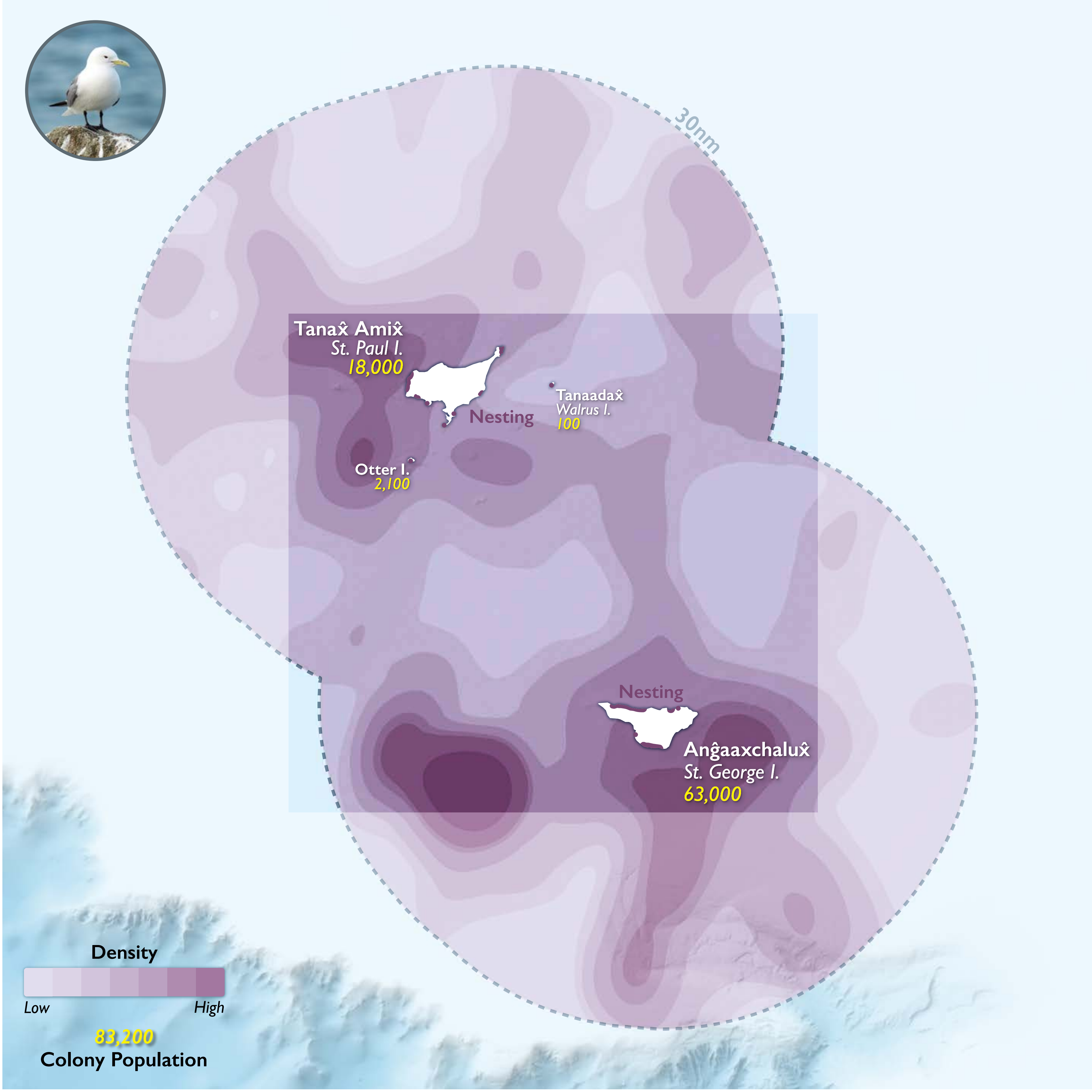
150NM

Black-Legged Kittiwake



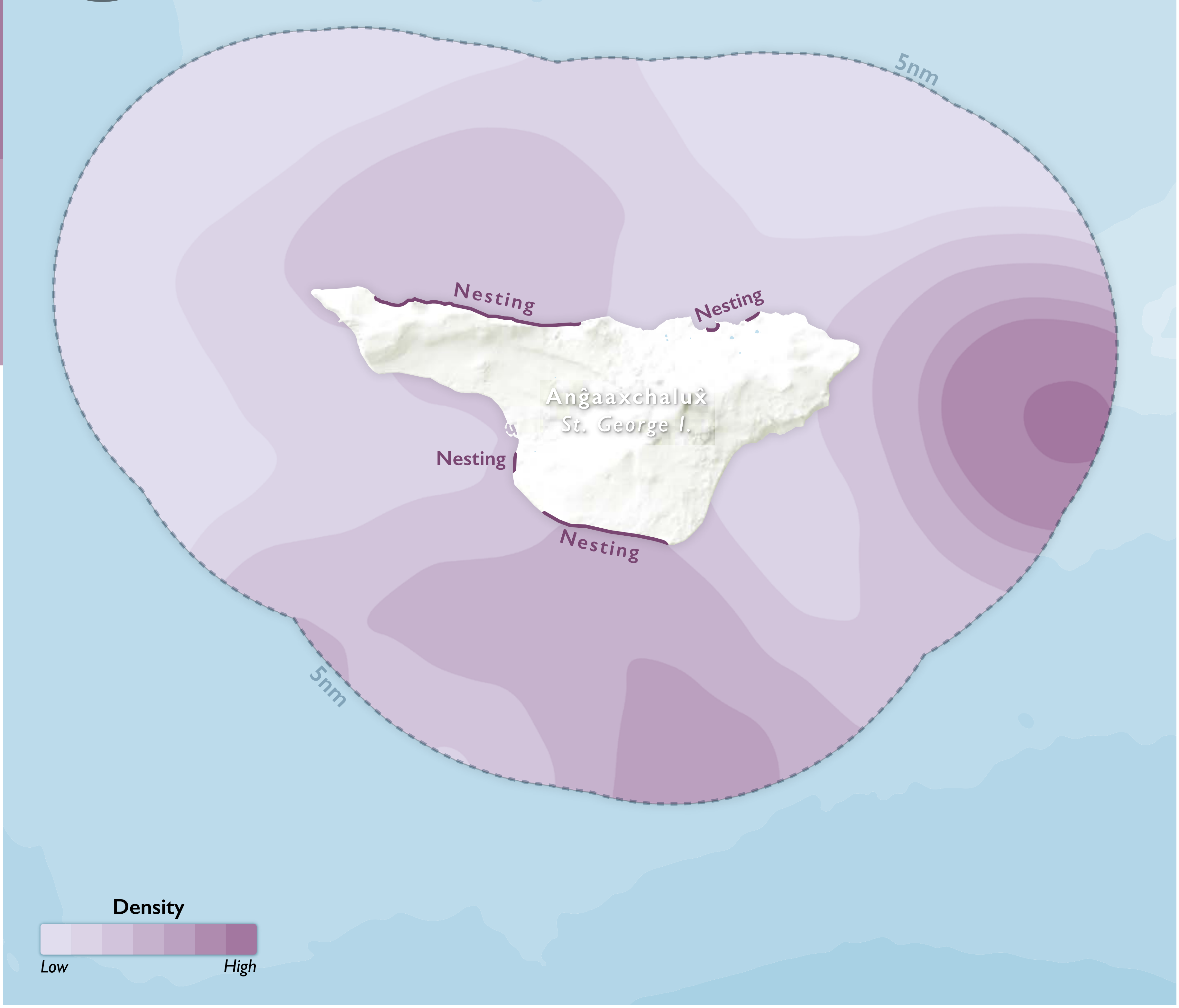
30NM

Black-Legged Kittiwake



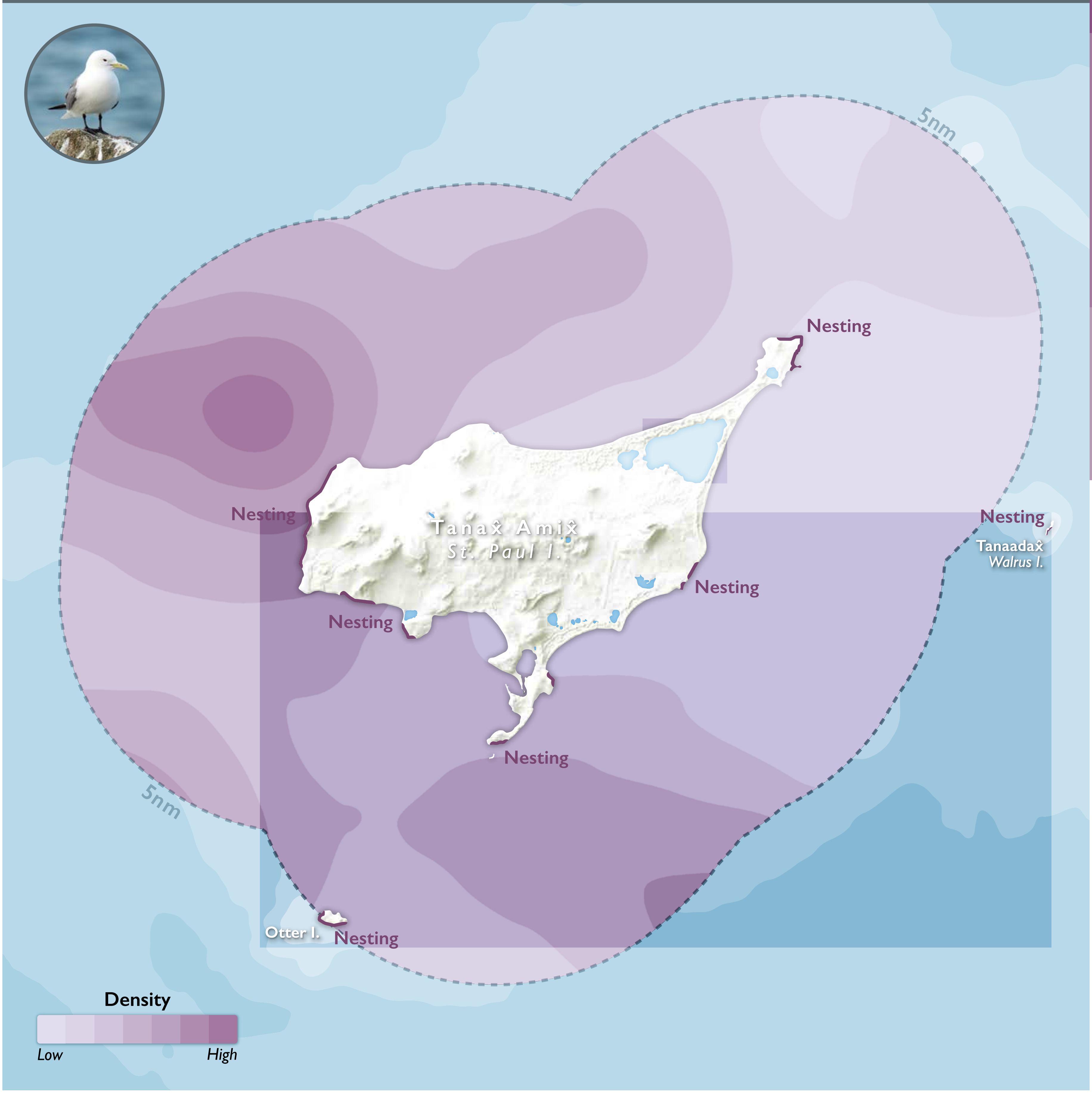
ST. GEORGE 5NM

Black-Legged Kittiwake



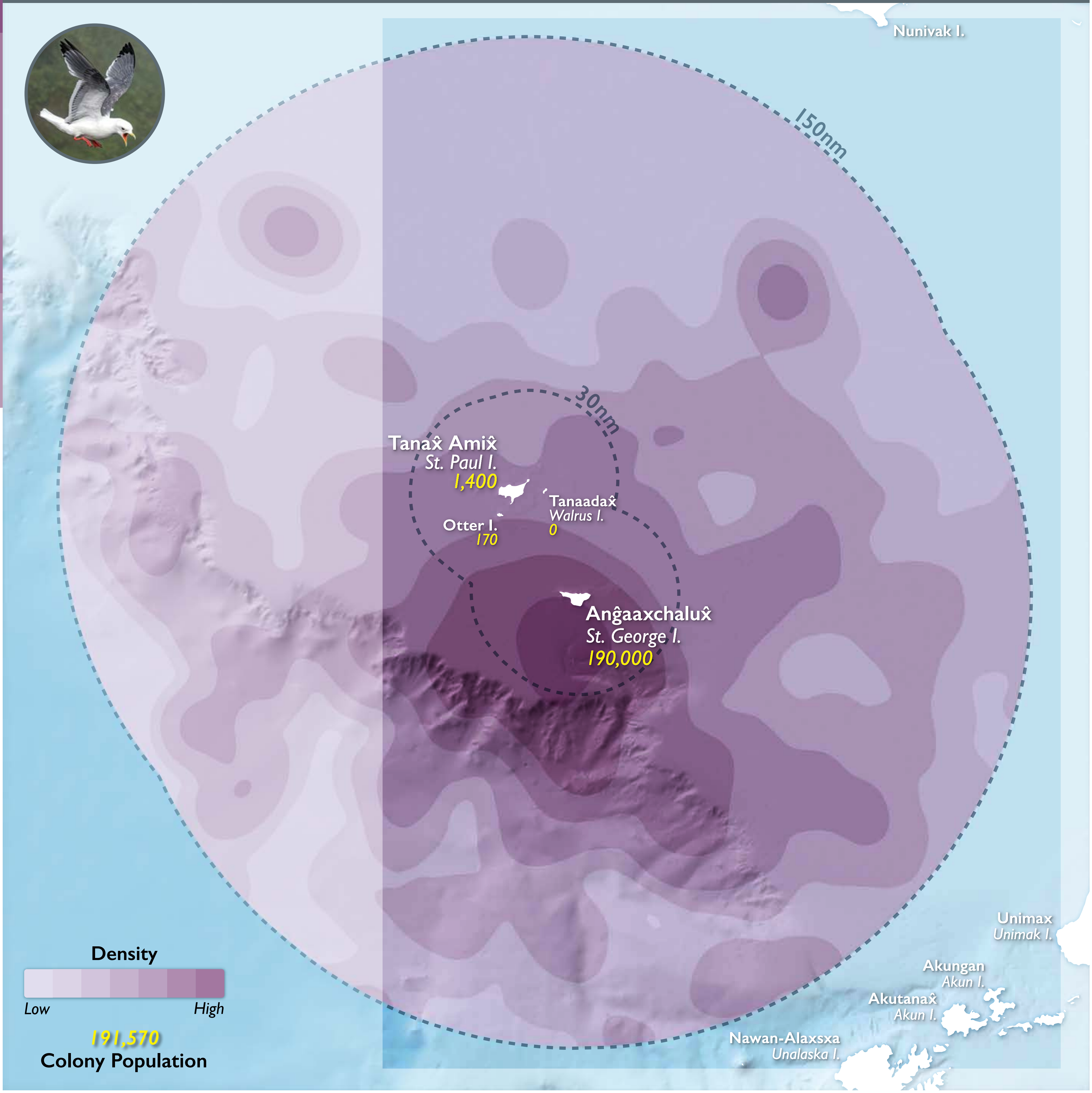
ST. PAUL 5NM

Black-Legged Kittiwake



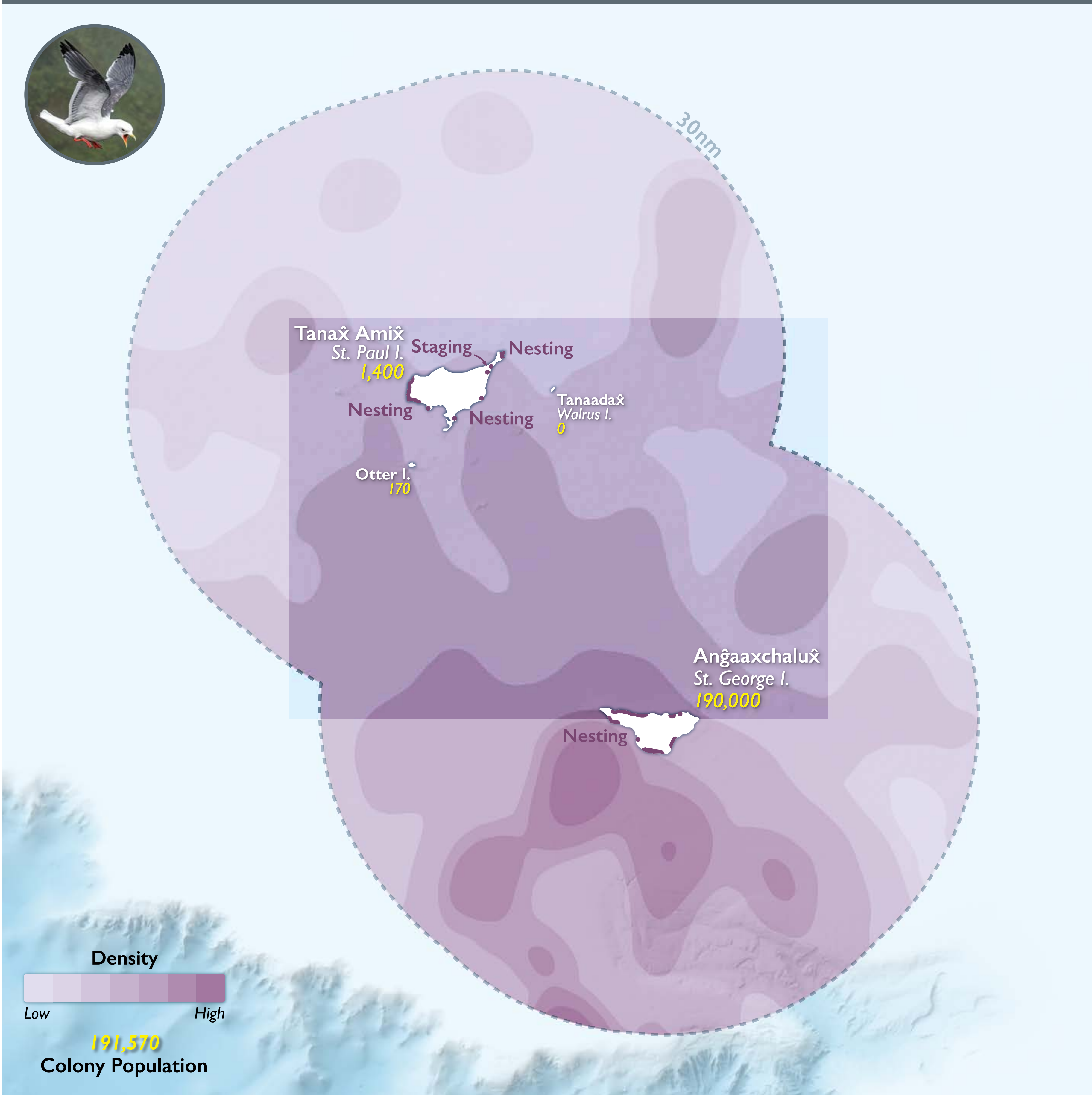
150NM

Red-Legged Kittiwake



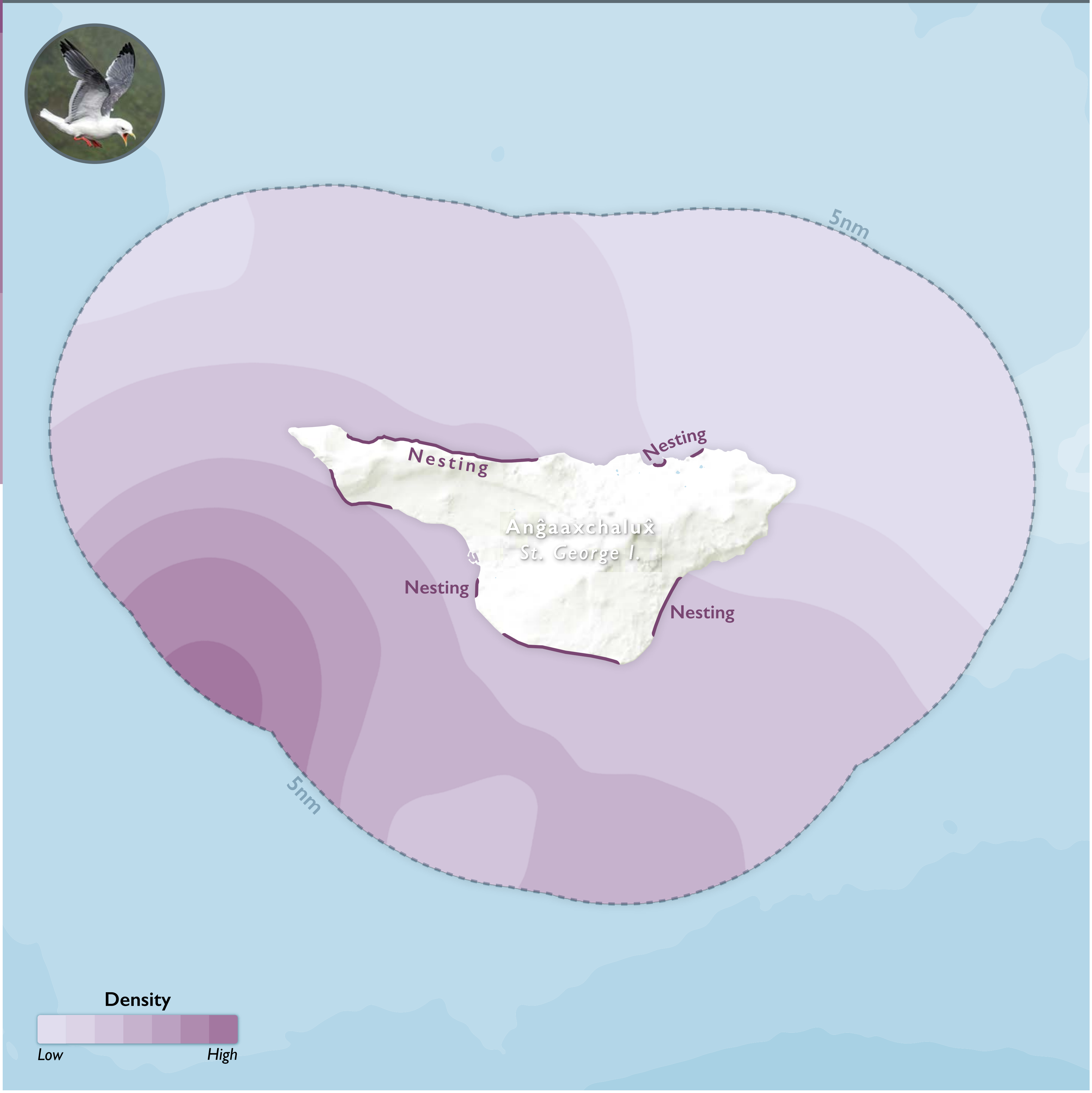
30NM

Red-Legged Kittiwake



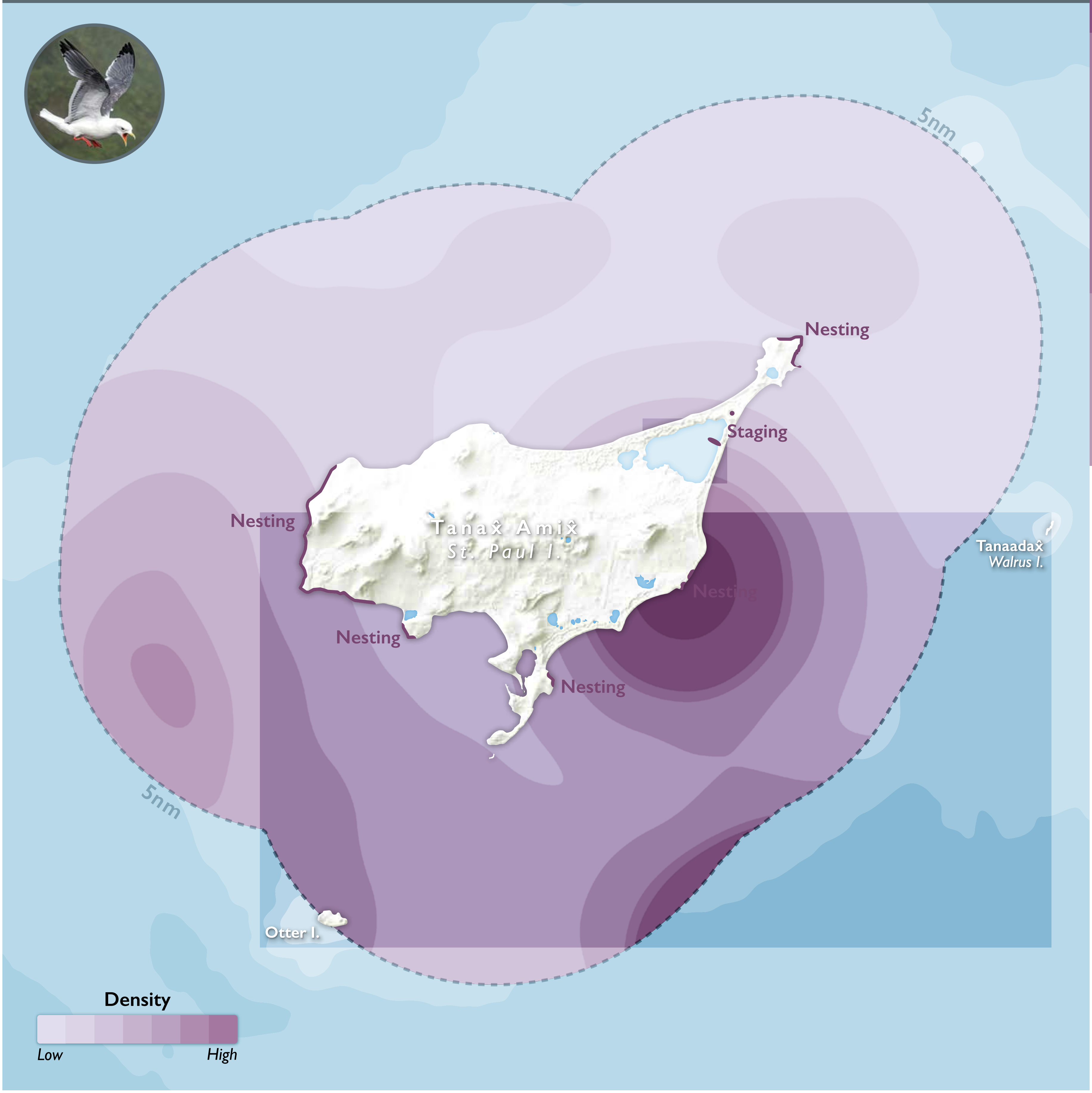
ST. GEORGE 5NM

Red-Legged Kittiwake



ST. PAUL 5NM

Red-Legged Kittiwake



Murres

The largest and most well-studied birds in the Auk family (Alcidae), the two congeneric species of murre, the *Sakitax̂* or Common Murre (*Uria aalge*) and *Ulux̂txax̂* or Thick-billed Murre (*U. lomvia*). *Sakitax̂* and *Ulux̂txax̂* are among the most abundant seabirds in the Northern Hemisphere. They are found in cooler, continental shelf waters of the Arctic and subarctic in North America, Europe, and eastern Asia, and live their entire lives on or very near the ocean, coming ashore only to breed (Gaston and Hipfner 2000; Wong et al. 2014). *Sakitax̂* and *Ulux̂txax̂* have dark brown or black heads, necks, upper wings, and backs and have white underparts. They use their short tails for propping themselves up when perched on the rocky cliffs on which they breed (Ainley et al. 2002). Both species have long, tapered black bills. The bill of *Sakitax̂* is finer than that of *Ulux̂txax̂*, which has a noticeable decurve at the tip, compared to the subtle taper of the *Sakitax̂*'s bill. The most distinctive field mark is a white line on the bill of *Ulux̂txax̂*, though this is difficult to observe from a distance. There are also minor differences in plumage between the two murres as well. *Sakitax̂* shows a curved, upside-down "U" on its upper chest at the margin between black and white feathers, while *Ulux̂txax̂* has a sharper, inverted "V" where black feathers meet white feathers on its chest (Ainley et al. 2002).

Murres have very short wings and a relatively large and heavy body, resulting in the highest wing-load of extant flighted birds (Croll et al. 1991). This high wing-load makes takeoff very difficult, and murres require an especially fast wing beat and flight speed to stay airborne (Croll et al. 1991). They are, however, well-suited for swimming and diving, regularly reaching depths of over 330 feet (100 meters) and dive durations of over 4 minutes (Piatt and Nettleship 1985).

Highly social, *Sakitax̂* and *Ulux̂txax̂* breed nearly shoulder to shoulder with other murres in colonies often composed of hundreds of thousands of breeding birds, as they appear at breeding locations on St. George and St. Paul. They do not build nests, and instead lay their eggs on the rocky substrate, slopes, and flat surfaces of the island cliff ledges (Stephensen and Irons 2003). By breeding in high numbers and high density, they are somewhat protected from large gulls (*Larus* spp.) that attempt to take chicks or steal food brought to chicks (Spear 1993). Murres lay their single, especially hard egg in a highly synchronous manner, with 90% of all eggs in a given colony laid within 15 days of each other (Murphy and Schauer 1996). The long, pointed shape of the egg is an adaptation that keeps it from rolling off the cliffside nest, as it instead rolls in a tight circle. Both sexes share equally in incubating the egg (Wanless and Harris 1986; Verspoor et al. 1987). If an egg is lost or gathered for subsistence use early enough in the breeding season, murres will re-lay another single egg.

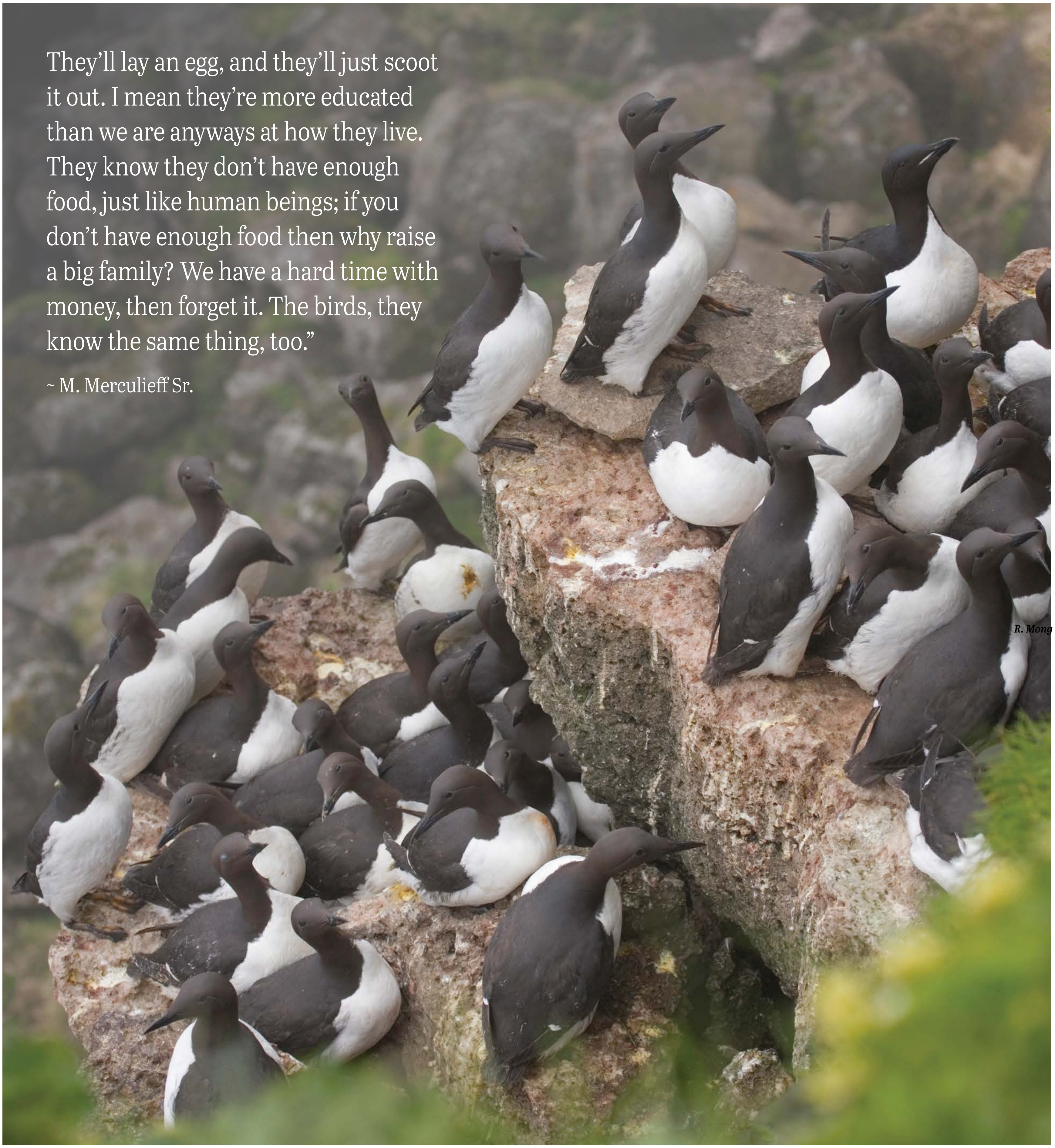
Adults share foraging responsibilities as well, and must seek abundant, energy-rich prey within 37–43 miles (60–70 km) of breeding ledges, as chicks are fed a single fish several times a day (Gaston and Hipfner 2000). Chicks leave the nest with their fathers at only three or four weeks old, well before they are capable of flight. This event is also highly synchronous, with large groups of male murres leading their young chicks to the cliff's edge, jumping into the water, then calling for the chicks to join them in the water (Roelke and Hunt 1978). If the chick becomes separated from its father, it is immediately surrounded by other murres until reunited through a duet of calls between the chick and parent. Back together, chicks then begin their first migration, swimming with their fathers until they are able to fly (Roelke and Hunt 1978). The female stays at the nest site for up to two weeks after her mate and chick have left, before flying south with non-breeding subadults (Gaston and Hipfner 2000).

Murres use their short, powerful wings for propulsion and capture prey in their bills. Unlike puffins, they generally catch a single fish at a time, repositioning the prey for swallowing headfirst while they are still under water (Sanford and Harris 1967; Swennen and Duiven 1977; Raikow et al. 1988). Although they are commonly found hunting by themselves, murres also forage cooperatively in flocks that often consist of thousands of seabirds of many species, such as shearwaters, cormorants, gulls, jaegers, kittiwakes, and other alcids. They are also often joined by marine mammals, including whales and dolphins foraging for fishes and invertebrates, such as Arctic cod (*Boreogadus saida*), saffron cod (*Eleginus gracilis*), walleye pollock, sand lance (*Ammodytes* spp.), capelin (*Mallotus villosus*), herring (*Clupea* spp.), euphausiids, large copepods, and squid. They feed mostly in the epibenthic and demersal zones, on or just above the ocean floor. The high energetic requirements of their northern latitude habitat, poor insulation, and high wing-loading require murres to consume 10–30% of their body mass each day (Johnson and West 1975; Swennen and Duiven 1977).

Starvation is a common cause of murre mortality, and dead murres are sometimes found in very large numbers. As recently as the winter of 2015–16, Common Murres in Alaska suffered a large mortality event of ~500,000 birds from the Gulf of Alaska to the Pribilof Islands, likely caused by a combination of climate factors such as atypically warm weather patterns and water temperatures leading to diminished forage-fish assemblages (Cavole et al. 2016). *Sakitax̂* population travel great distances, even to inland locations in search of food. Suffering diminished body condition, and many starved.

They'll lay an egg, and they'll just scoot it out. I mean they're more educated than we are anyways at how they live. They know they don't have enough food, just like human beings; if you don't have enough food then why raise a big family? We have a hard time with money, then forget it. The birds, they know the same thing, too."

~ M. Merculieff Sr.



R. Mong

M. Burcham

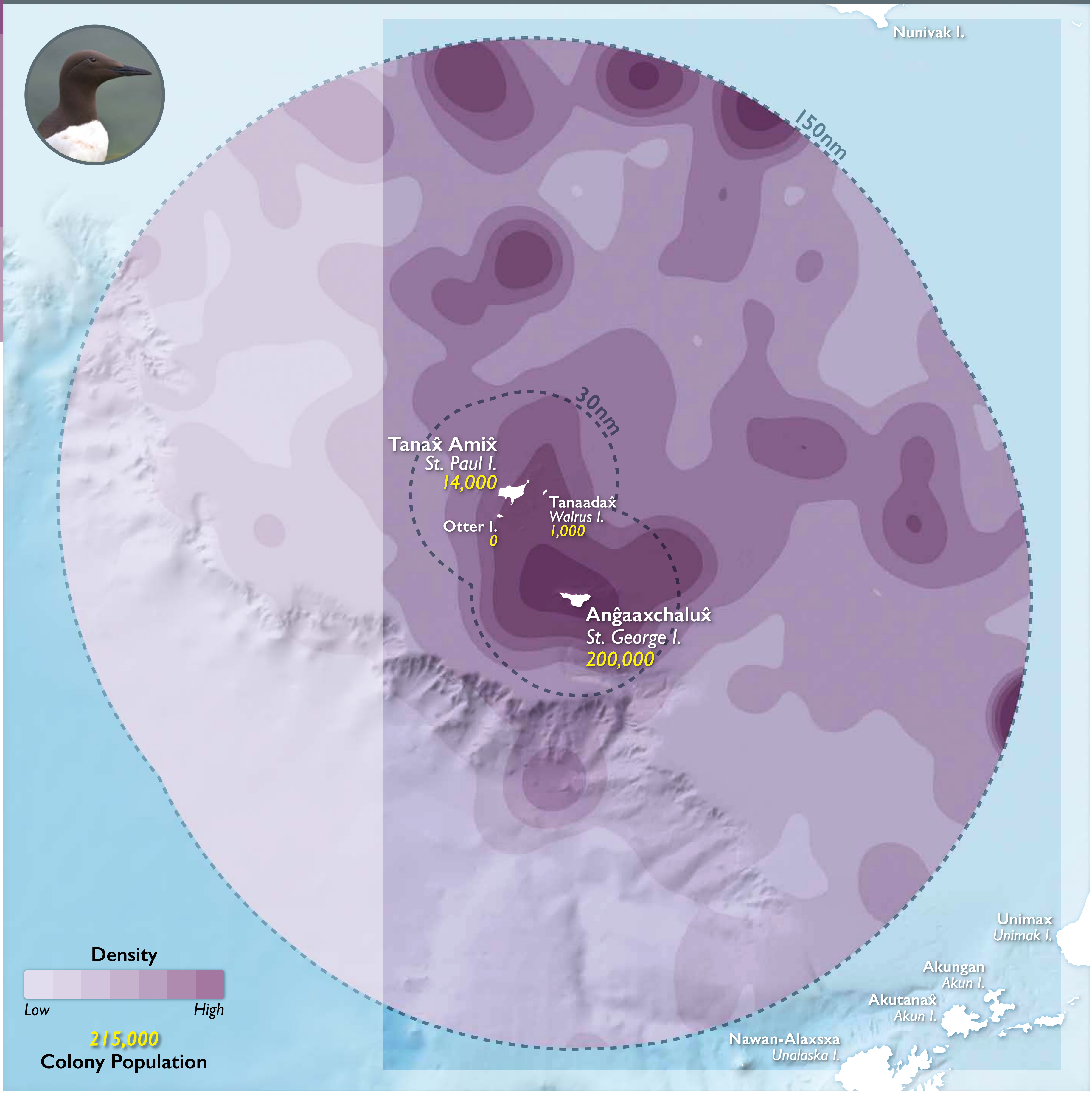
BIRDS

COMMON MURRE

150NM

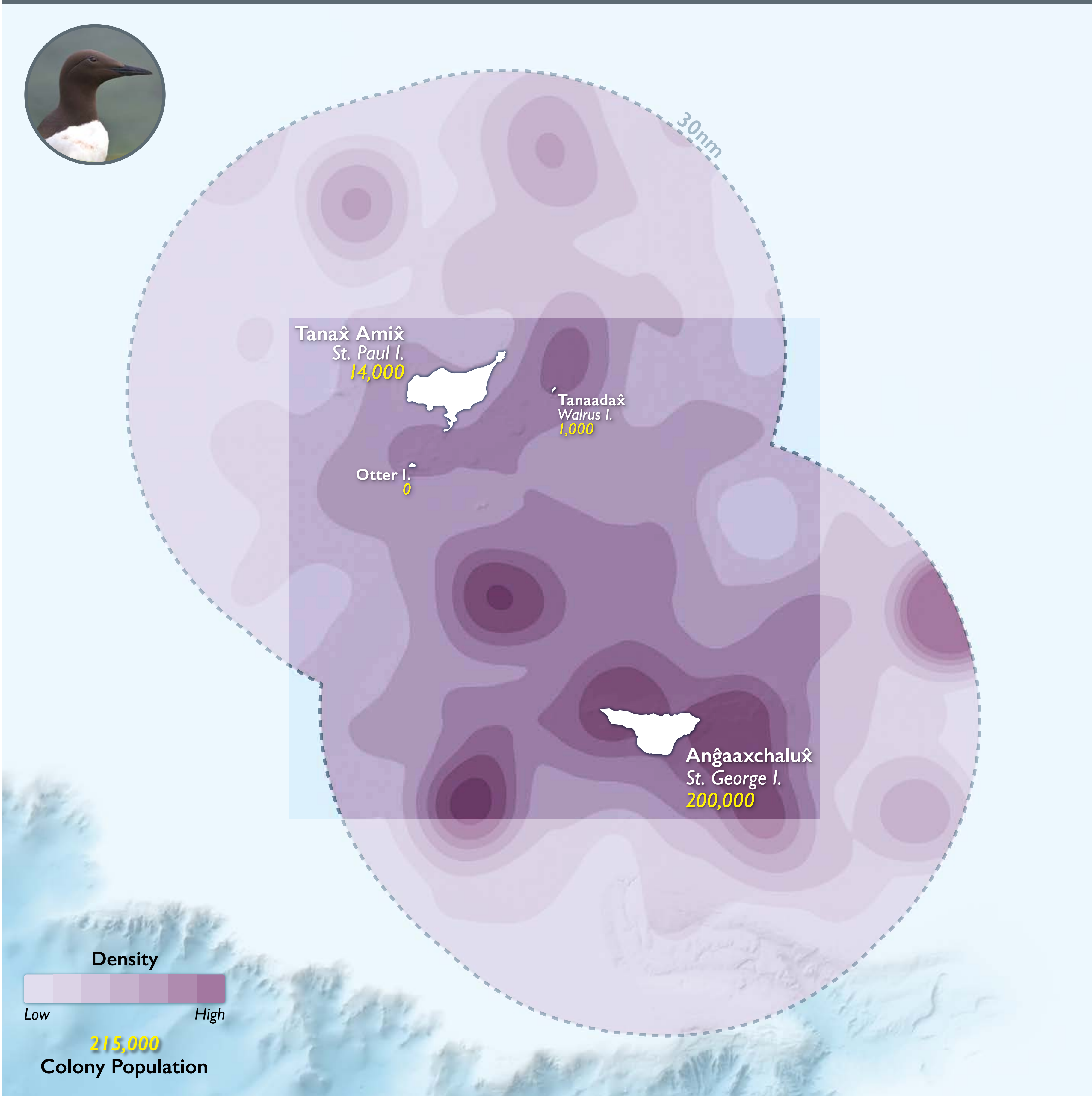
150NM

Common Murre



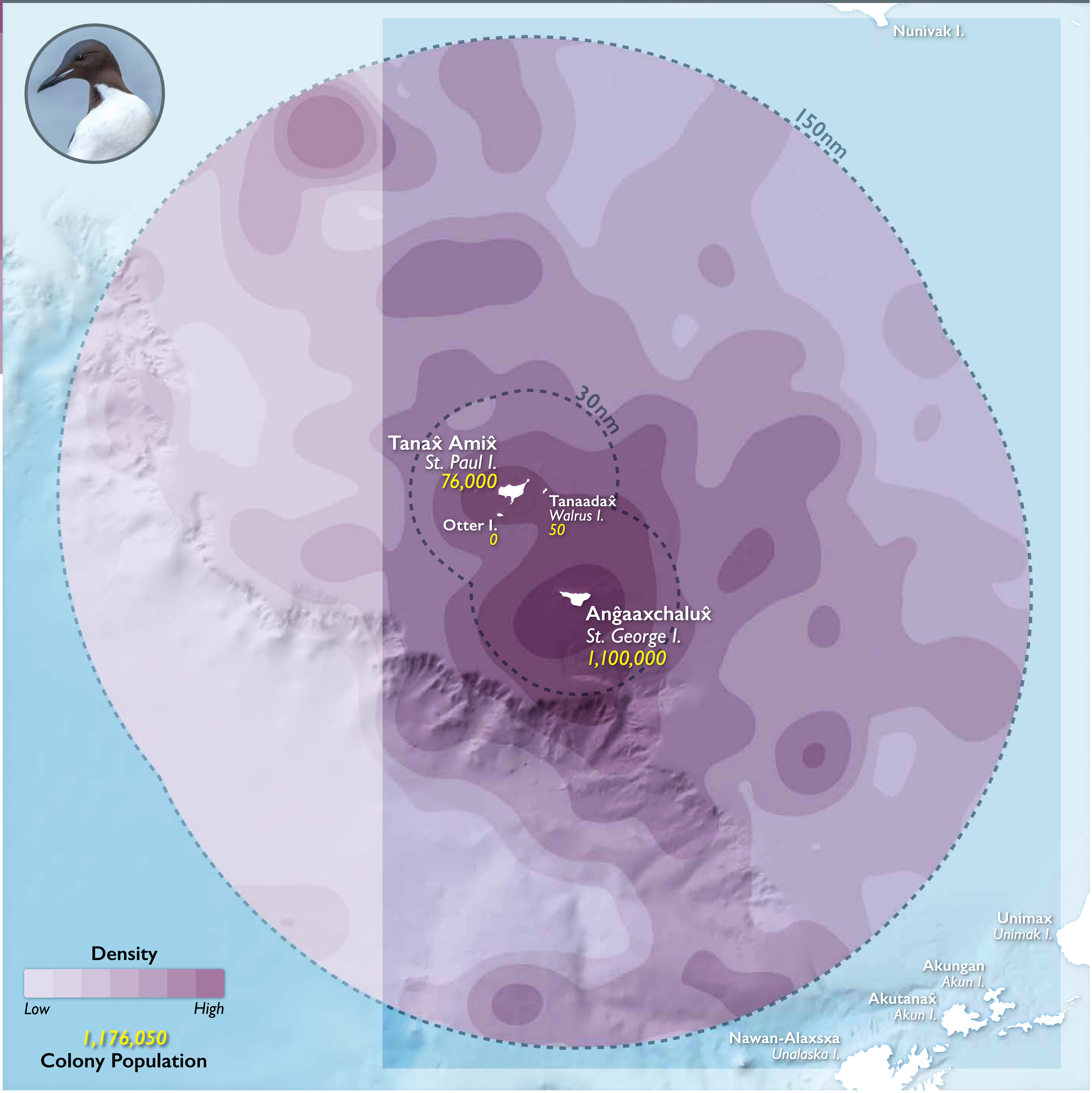
30NM

Common Murre



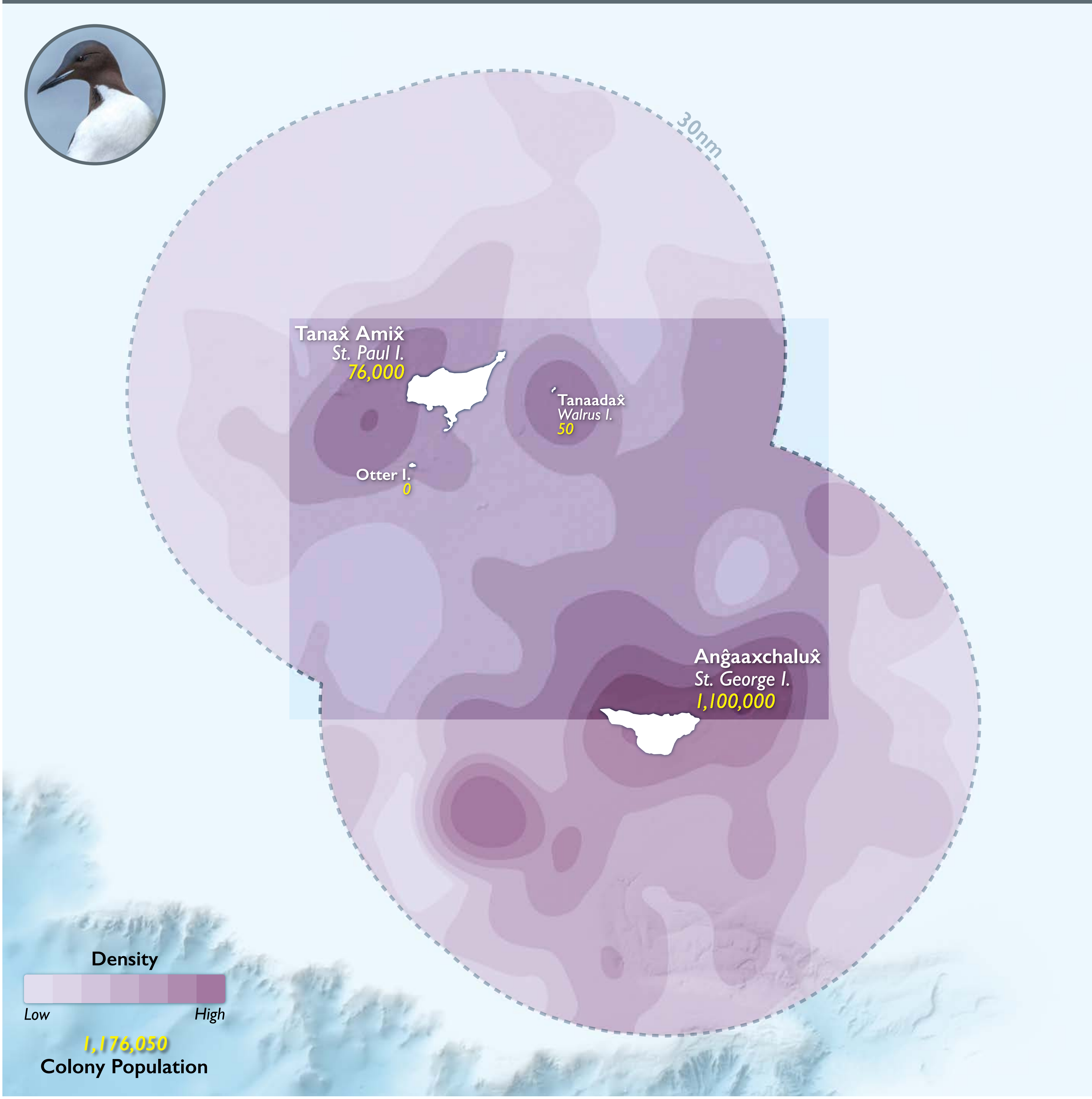
150NM

Thick-billed Murre



30NM

Thick-billed Murre



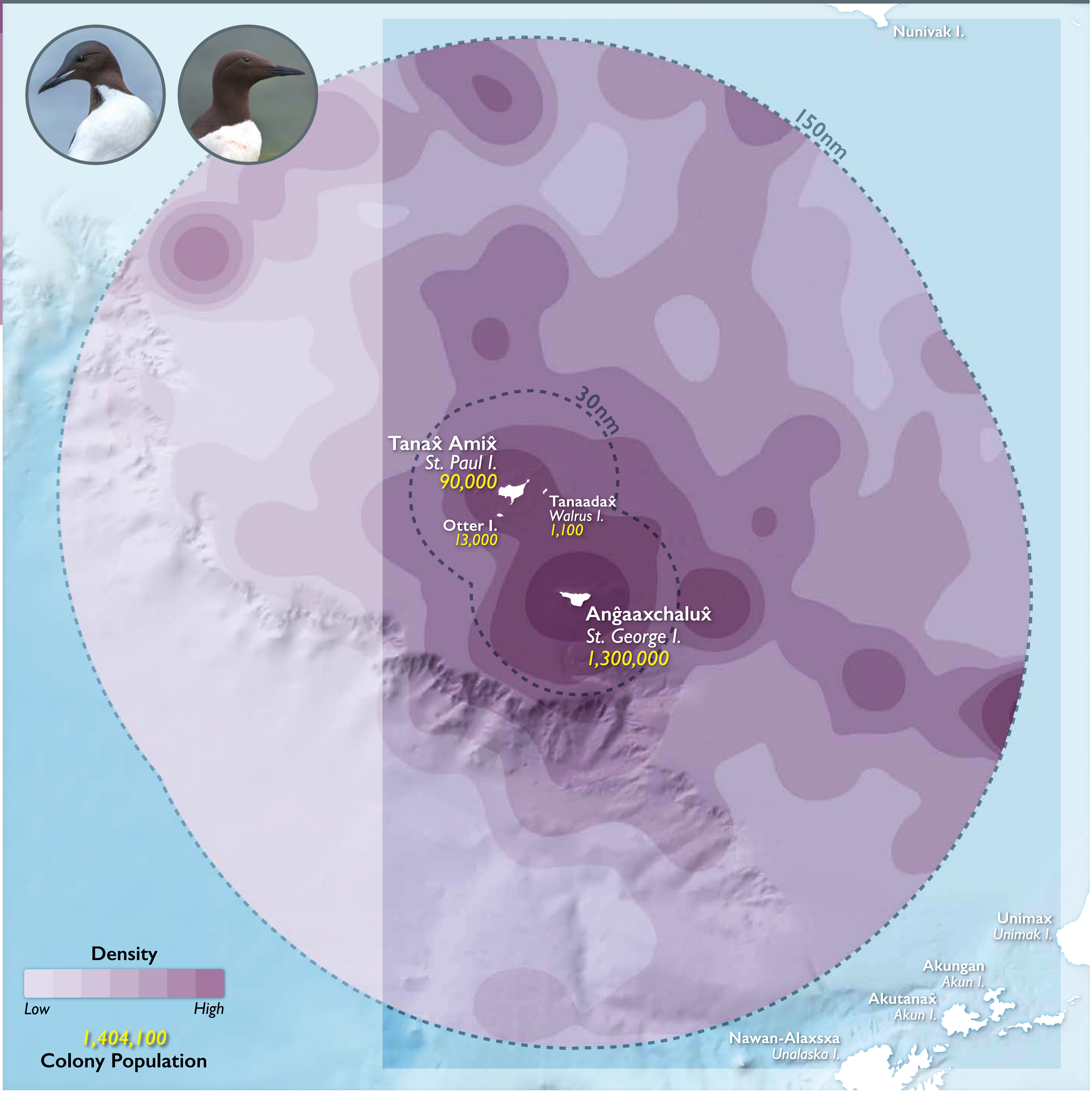
BIRDS

TOTAL MURRES

150NM

150NM

Total Murres



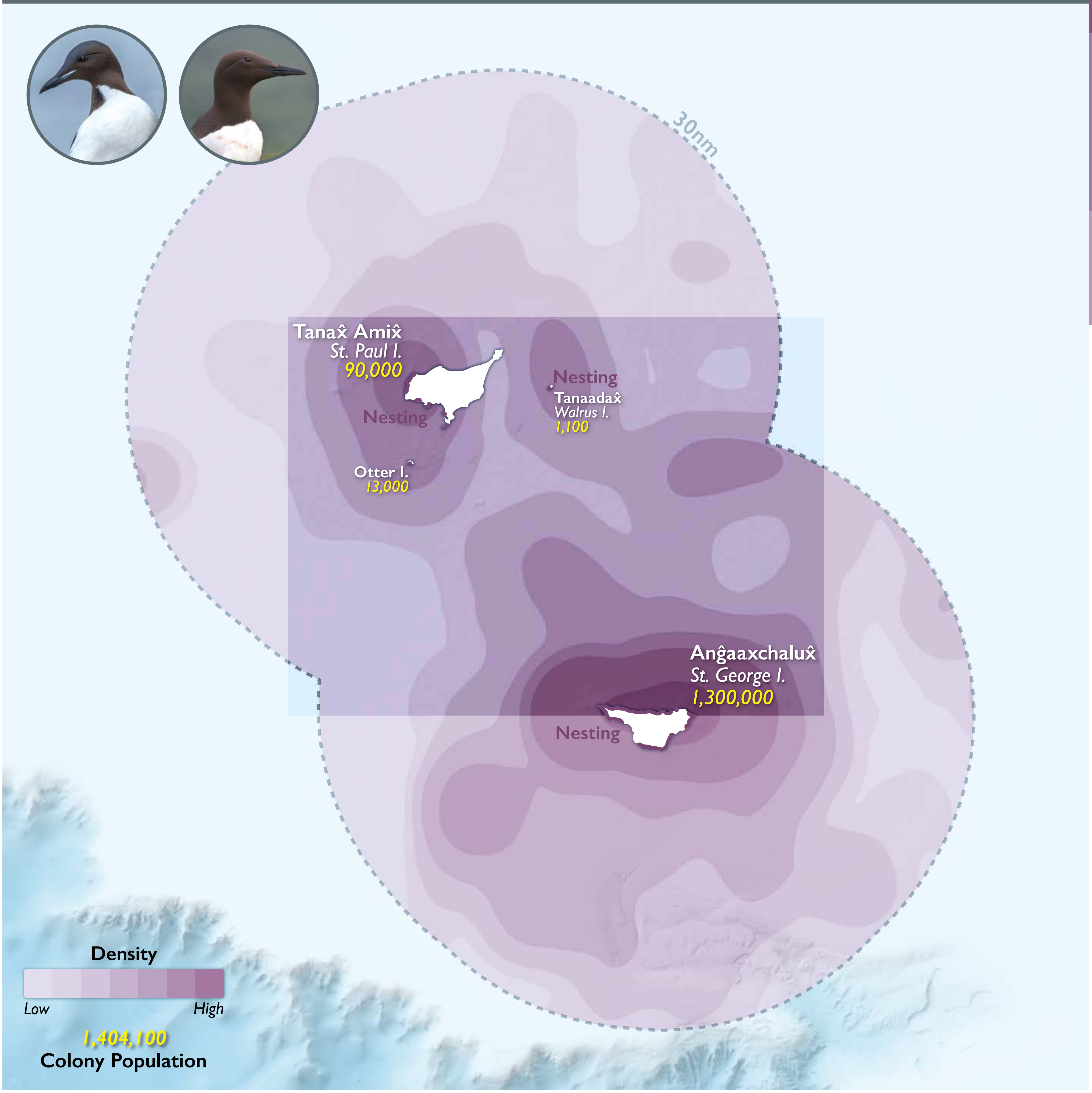
30NM

Total Murres

BIRDS

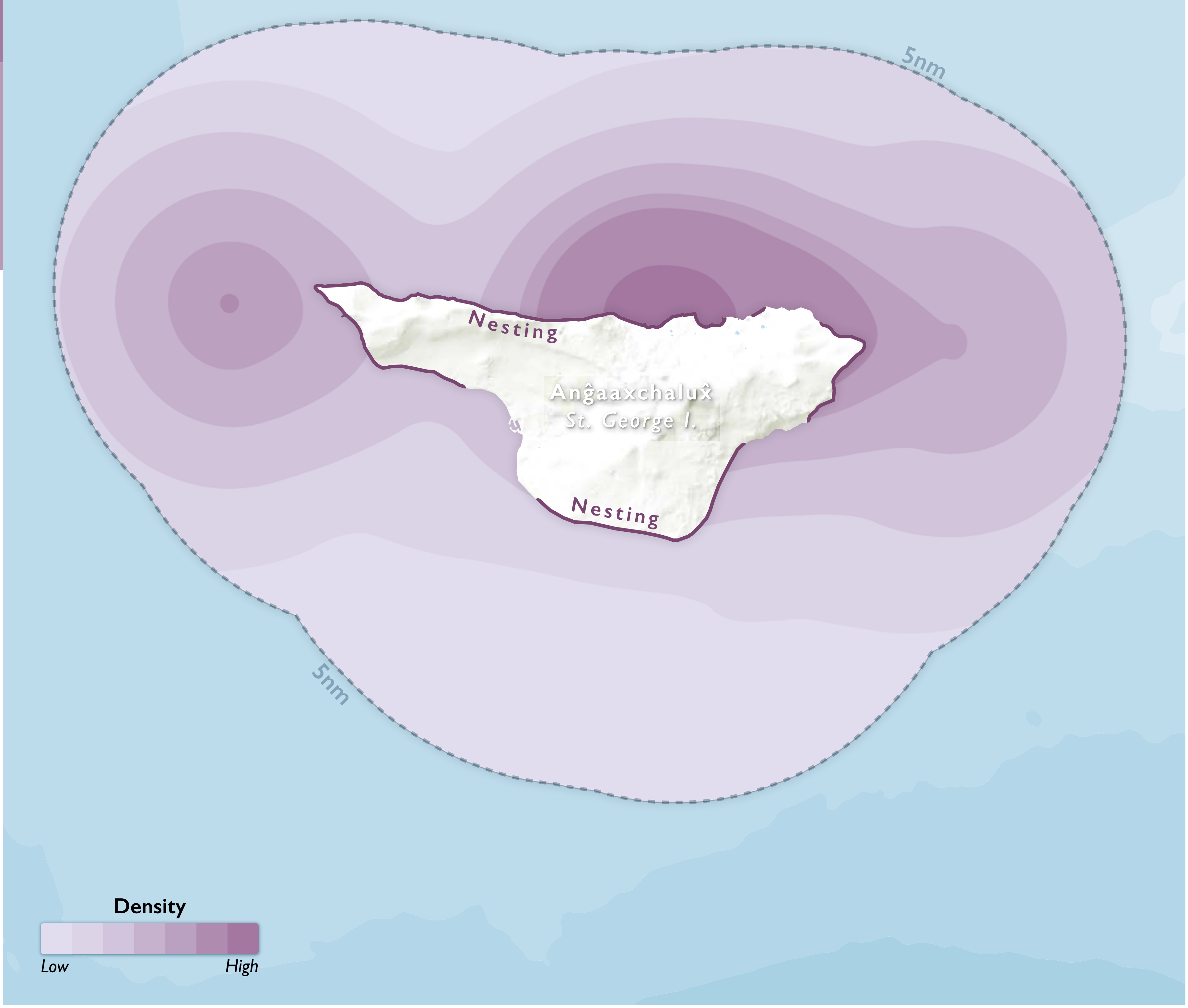
TOTAL MURRES

30NM



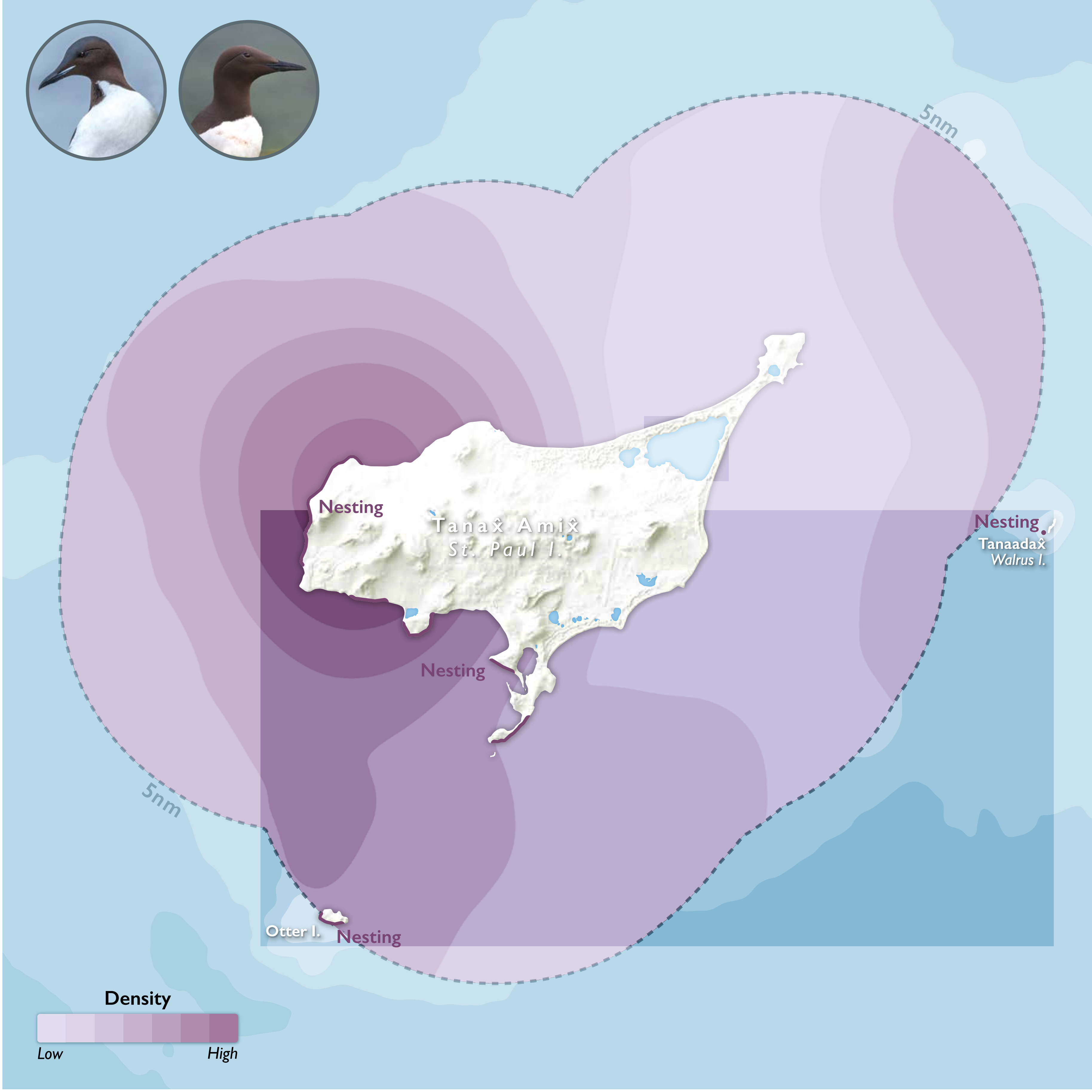
ST. GEORGE 5NM

Total Murres



ST. PAUL 5NM

Total Murres



Puffins

Among the most iconic and well-known species of the Arctic, *Qagidax̂* or Horned Puffins (*Fratercula corniculata*) and *Uxchux̂* or Tufted Puffins (*F. cirrhata*) are ornate, diving seabirds that nest colonially among the numerous coastal cliffs of the Arctic and subarctic. Closely related to (and in the case of the Horned Puffin, closely resembling) the Atlantic Puffin (*F. arctica*), they are adapted to many climatic regimes, utilizing the frigid and often ice-covered waters of the Chukchi Sea down to the subtropical currents of the central North Pacific Ocean (Gaston and Jones 1998). In the Pribilof Islands, puffins are called 'Sea Parrots'.

Qagidax̂ and *Uxchux̂* share many physical traits and adaptations, but are relatively easy to distinguish visually. Adult *Uxchux̂* are covered in brownish-black plumage, with a large, white face-mask; a large, grooved, orange bill; and long, golden head-plumes that curve down the neck (Piatt and Kitaysky 2002a, b). Their legs and feet are bright yellowish to almost red, and their short neck becomes shorter during flight when they retract it into their shoulders (Gaston and Jones 1998). In contrast, *Qagidax̂* have a tall, narrow, deeply curved, bright-yellow bill, with a reddish tip and grooves along its edges for holding fish (Bédard 1969a). They have distinct facial patches: an orange patch at the gape, and a fleshy, black horn-like protrusion above their orange eye that earns them their name. *Qagidan* legs are also bright yellowish to almost red, and their necks are similarly short. However, they are especially distinct from *Uxchun* in flight, as they have a clearly visible white breast (Gaston and Jones 1998; Piatt and Kitaysky 2002a).

Puffins are excellent swimmers, and regularly dive 180 feet (60 m) or more to capture prey (Bédard 1969a). They use their wings to propel themselves through the water. This marine aptitude comes at a cost, however, and puffins are not exceptional fliers. They require a long stretch of water surface to take off, and their rapid wingbeats propel them on an especially direct flight path, without much opportunity for maneuvering (Gaston and Jones 1998). After foraging, they are often too laden to successfully take flight, and instead will dive to evade disturbance.

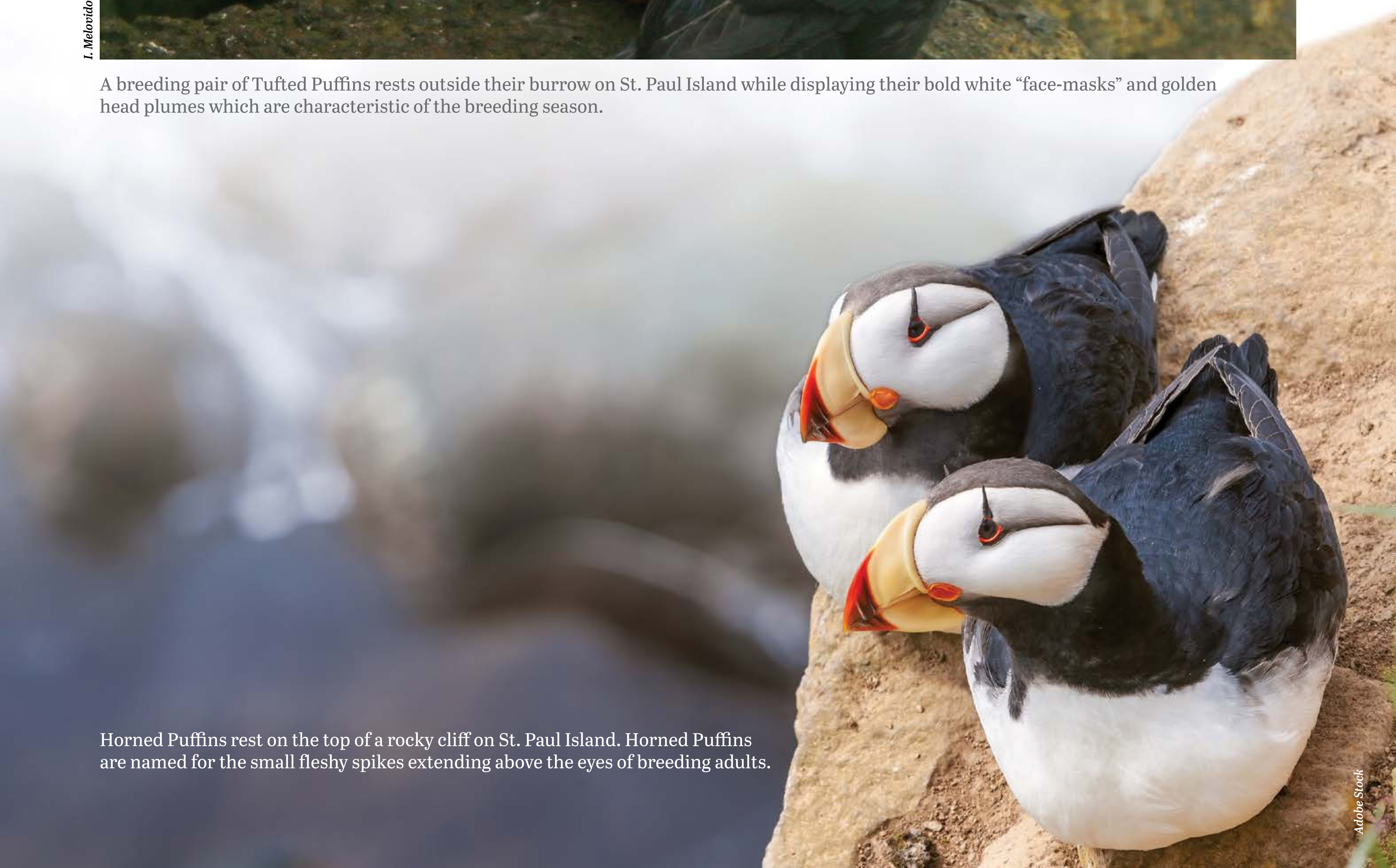
Puffins begin to occupy steep, cliffside breeding colonies in the Bering Sea in early May (Hatch and Hatch 1983; Harding 2001). Mates arrive in pairs, or begin forming pairs immediately after arrival at the breeding grounds (Sealy 1973; Wehle 1976, 1980; Harding 2001); these pairs are established within one week and are likely monogamous within each season. Puffins excavate burrows with their claws and bills in the rocky soil on steep slopes well above the shoreline, then line their nests with nearby grasses, feathers, fishing line, or algae. *Qagidan* are more likely to use a crevice to nest than are *Uxchun*, although both dig burrows (Piatt and Kitaysky 2002a, b). The presence of Pribilof foxes (*Alopex lagopus pribilofensis*) will catalyze a move to crevices, caves or more inaccessible habitat. The male puffin will defend the female at the nest and on the water with aggressive movements and chasing behavior. Within three to four weeks of mating, a single egg is laid, and parents take turns incubating it with their featherless brood patches. Chicks begin to hatch after 5 or 6 weeks of incubation, and parents will brood their newly hatched chick for one week (Harding 2001; Piatt and Kitaysky 2002a, b). Most breeding puffins depart the colony within 2 to 3 weeks after chicks are fledged each breeding season (Elphick and Hunt 1993; Morrison et al. 2009).

Adult puffin diets consist of mostly soft-bodied organisms, although they predominately feed their young with schooling fishes, such as capelin (*Mallotus villosus*), lanternfish (especially Myctophidae), juvenile pollock (*Gadus chalcogramma*), rockfish (*Sebastes* spp.), greenling (Hexagrammidae), and sand lance (*Ammodytes* spp.; Piatt et al. 1992; Piatt and Kitaysky 2002a, b; Piatt and Springer 2003; Sydeman et al. 2016). They capture their prey by diving and propelling themselves through the water with their wings (Bédard 1969a). Puffins eat their prey under water, unless they are foraging for their young, in which case they orient their prey perpendicular to their bills, which can hold up to 20 fish at once, a unique quality among seabirds (Bédard 1969a). While their maximum dive depth likely reaches over 300 feet (100 m), they usually forage in water less than 200 feet deep (60 m; Piatt and Nettleship 1985).

In the fall and winter of 2016/2017, St. Paul Island experienced a mortality event of *Uxchux̂*; St. George appeared to be unaffected (Jones et al. 2019). The event was particularly anomalous given the late fall/winter timing when encountering high numbers of beached birds is atypical. Collected specimens were severely emaciated, suggesting starvation as the ultimate cause of mortality. Additionally the majority of *Uxchux̂* were adults re-growing flight feathers, indicating a potential weakened state from molt stress. Immediately prior to this event, shifts in zooplankton community composition and in forage fish distribution and energy density were documented in the eastern Bering Sea following a period of elevated sea surface temperatures, evidence cumulatively suggestive of a bottom-up shift in seabird prey availability (Jones et al. 2019).

I. Melovidov

A breeding pair of Tufted Puffins rests outside their burrow on St. Paul Island while displaying their bold white “face-masks” and golden head plumes which are characteristic of the breeding season.

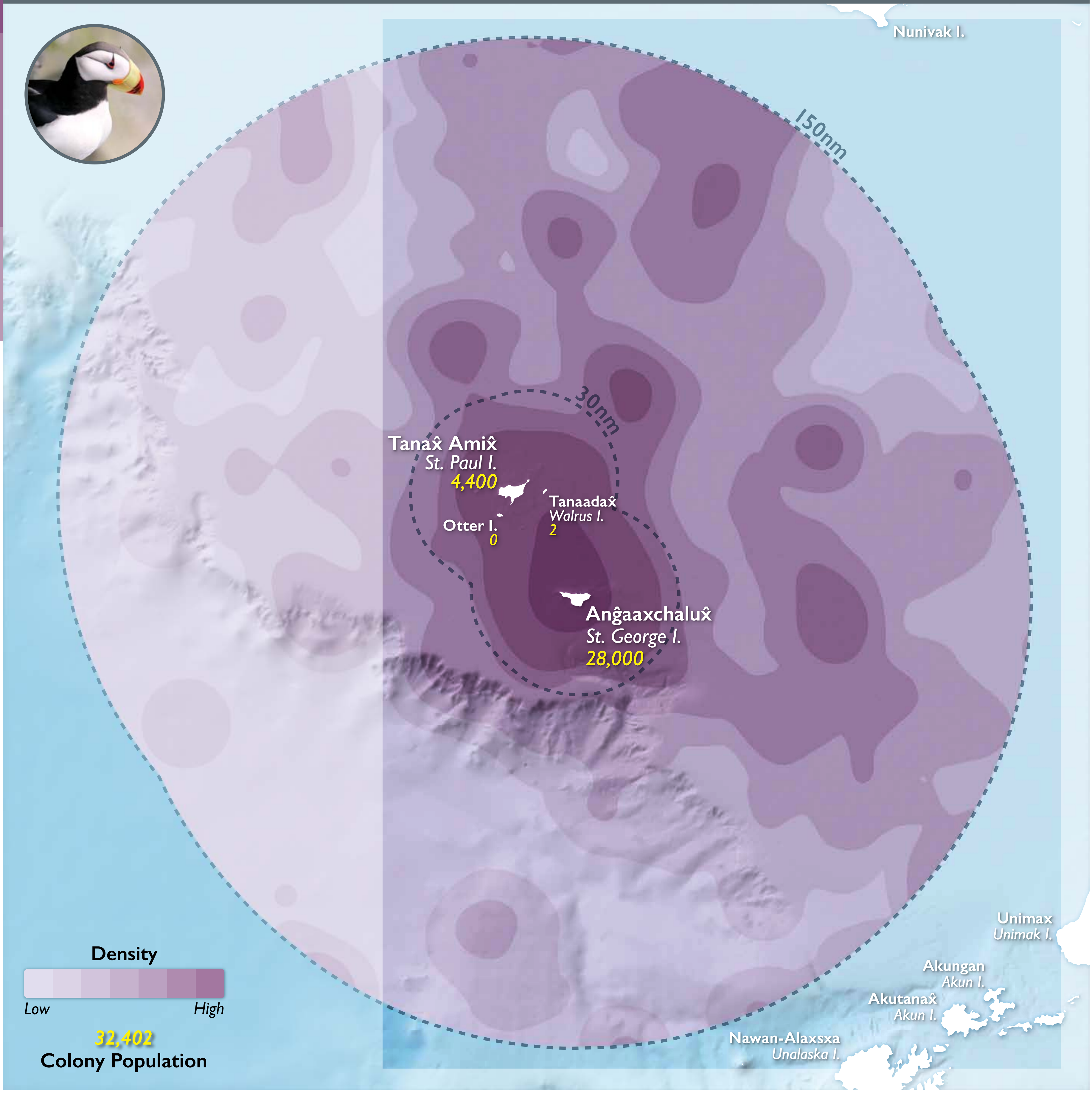


Horned Puffins rest on the top of a rocky cliff on St. Paul Island. Horned Puffins are named for the small fleshy spikes extending above the eyes of breeding adults.

Adobe Stock

150NM

Horned Puffin



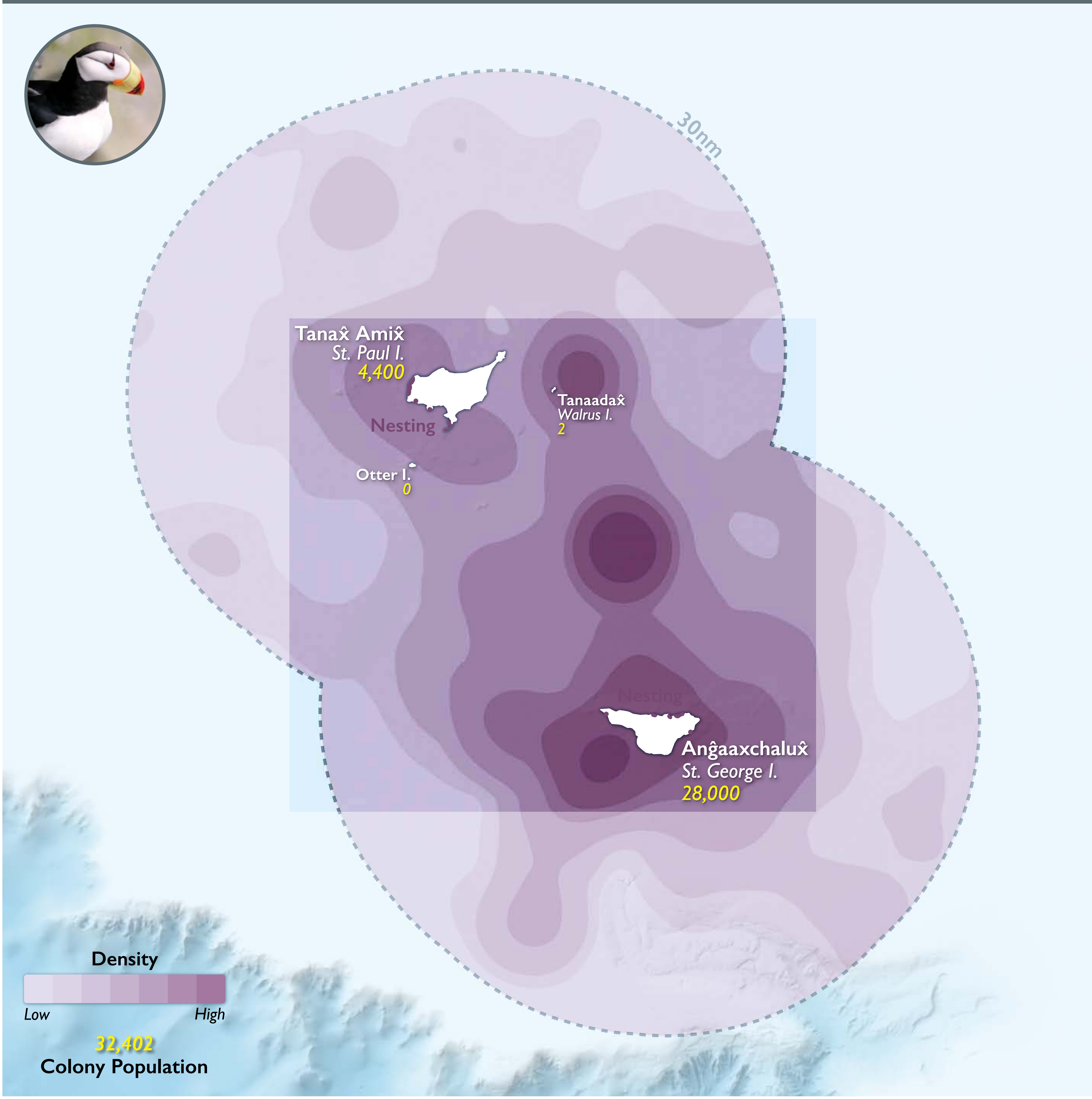
30NM

Horned Puffin

CITY of ST GEORGE

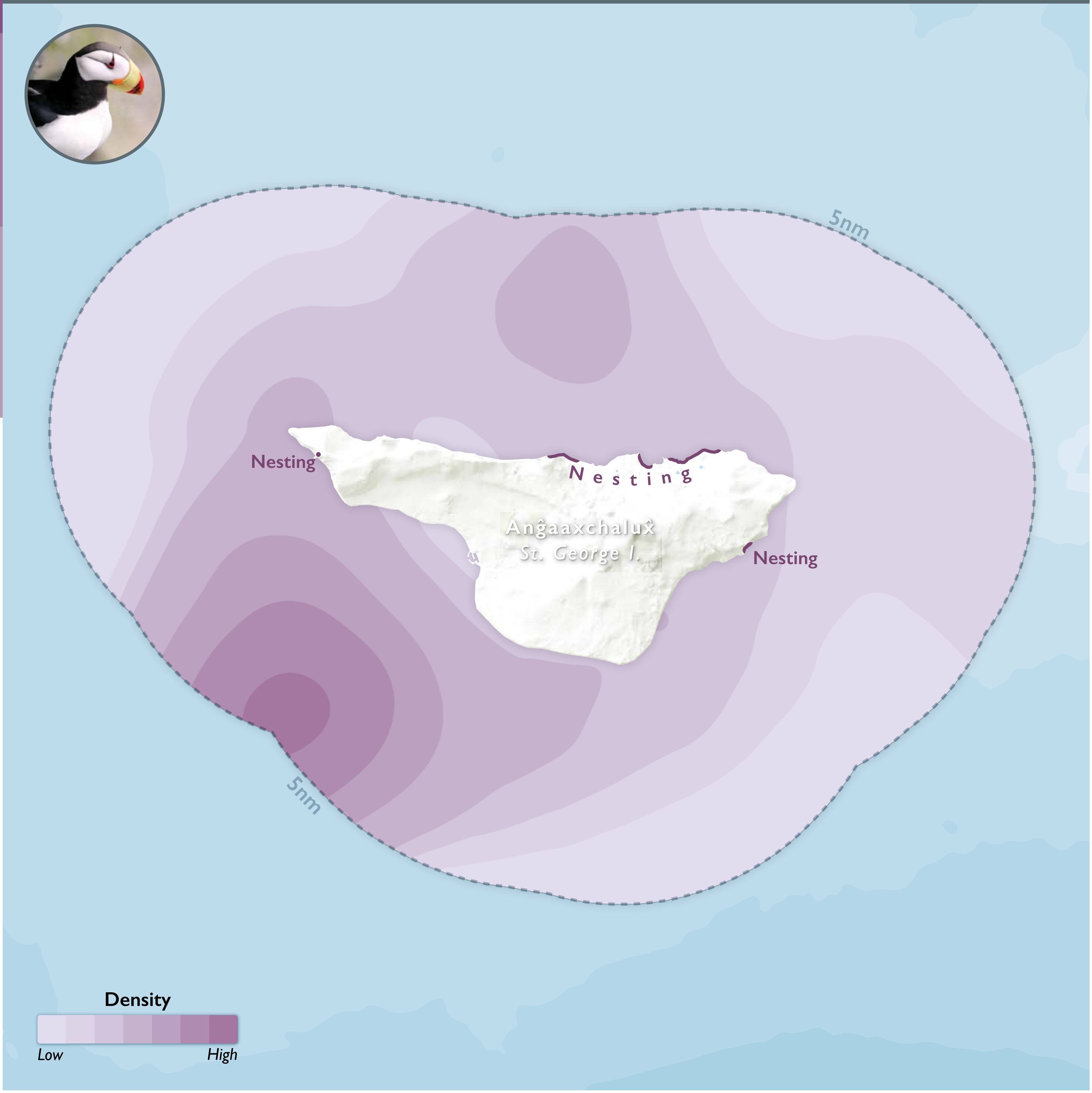
ALEUT COMMUNITY OF ST. PAUL TRIBAL GOVERNMENT

Audubon | ALASKA



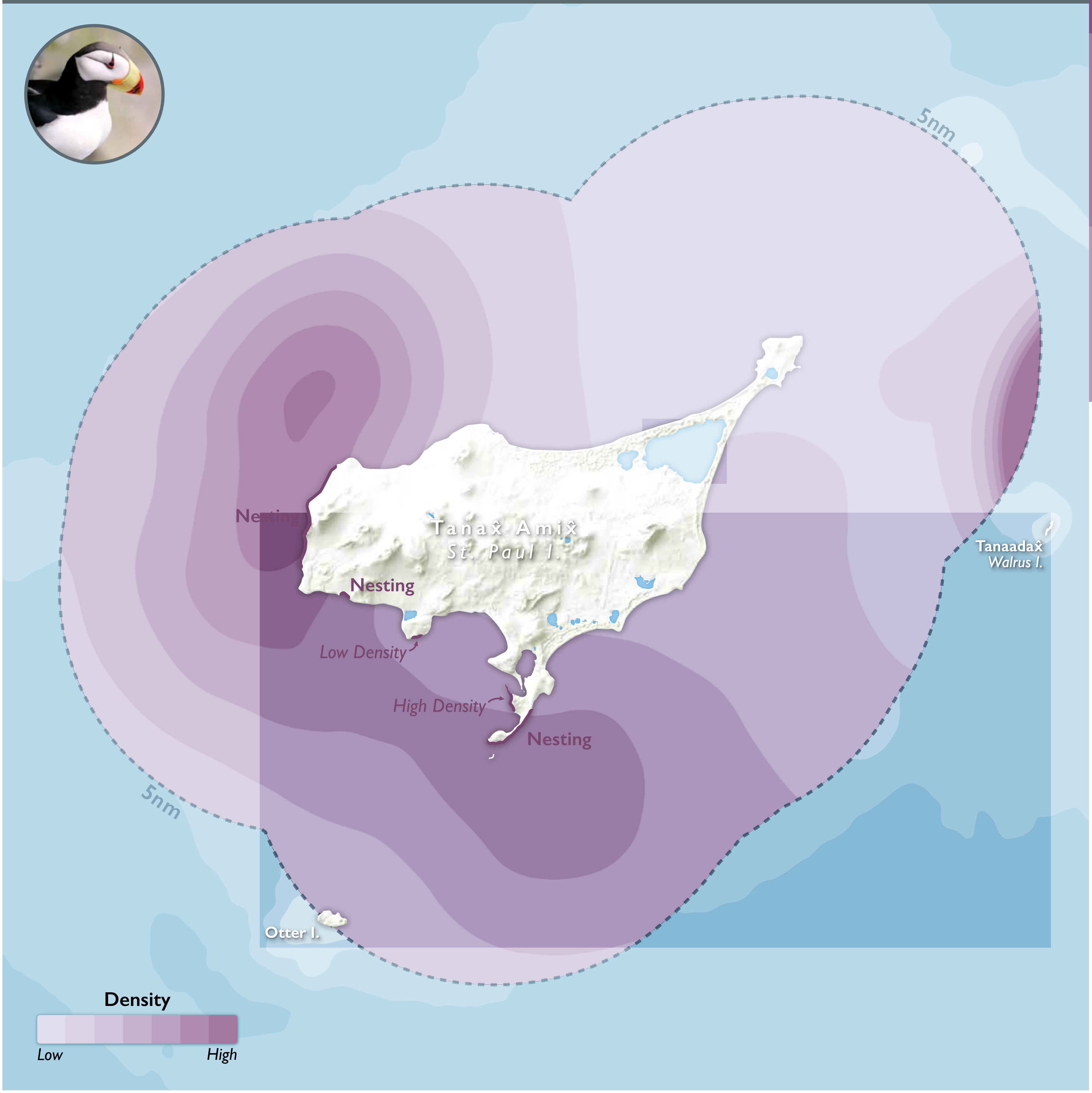
ST. GEORGE 5NM

Horned Puffin



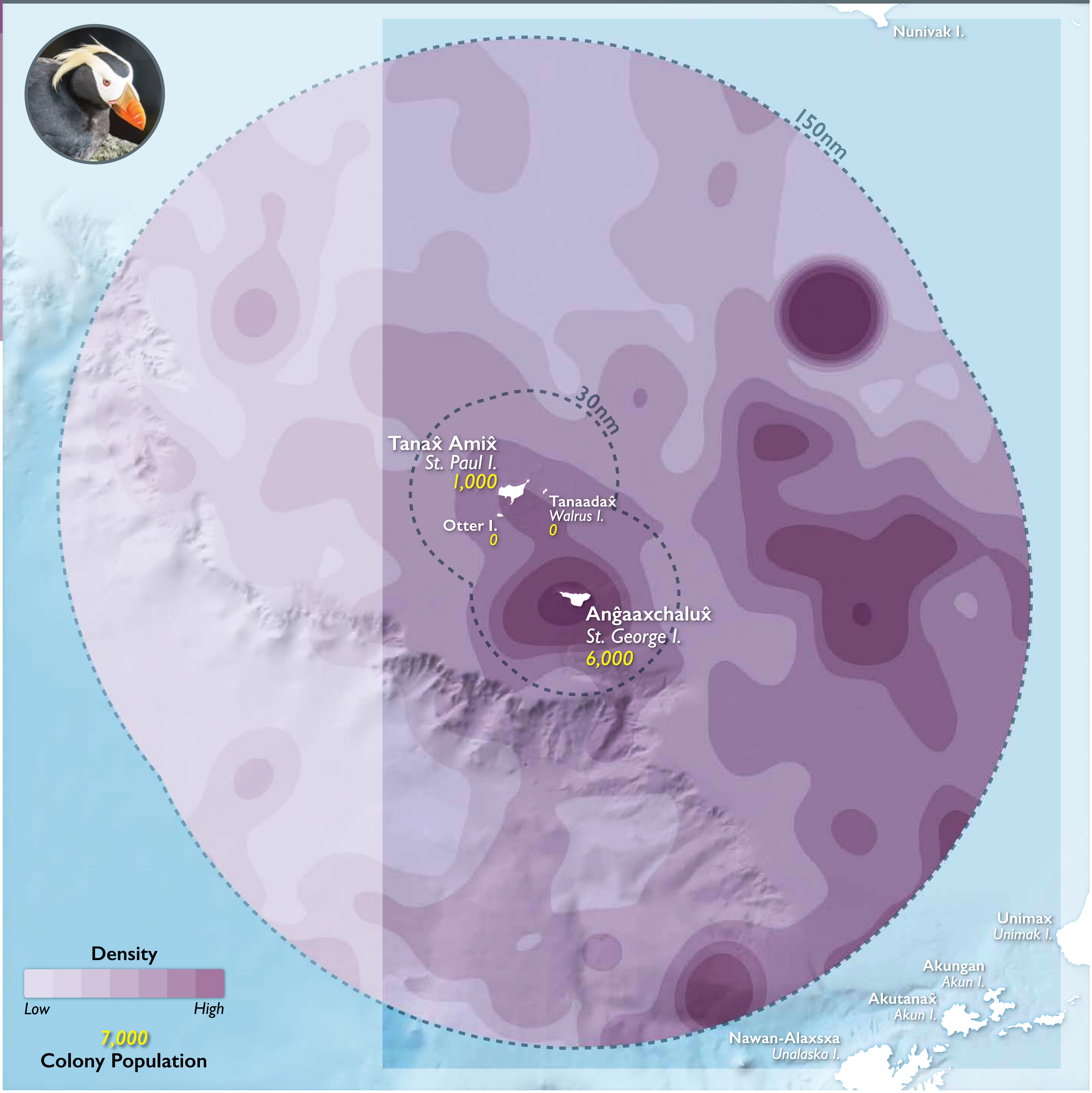
ST. PAUL 5NM

Horned Puffin



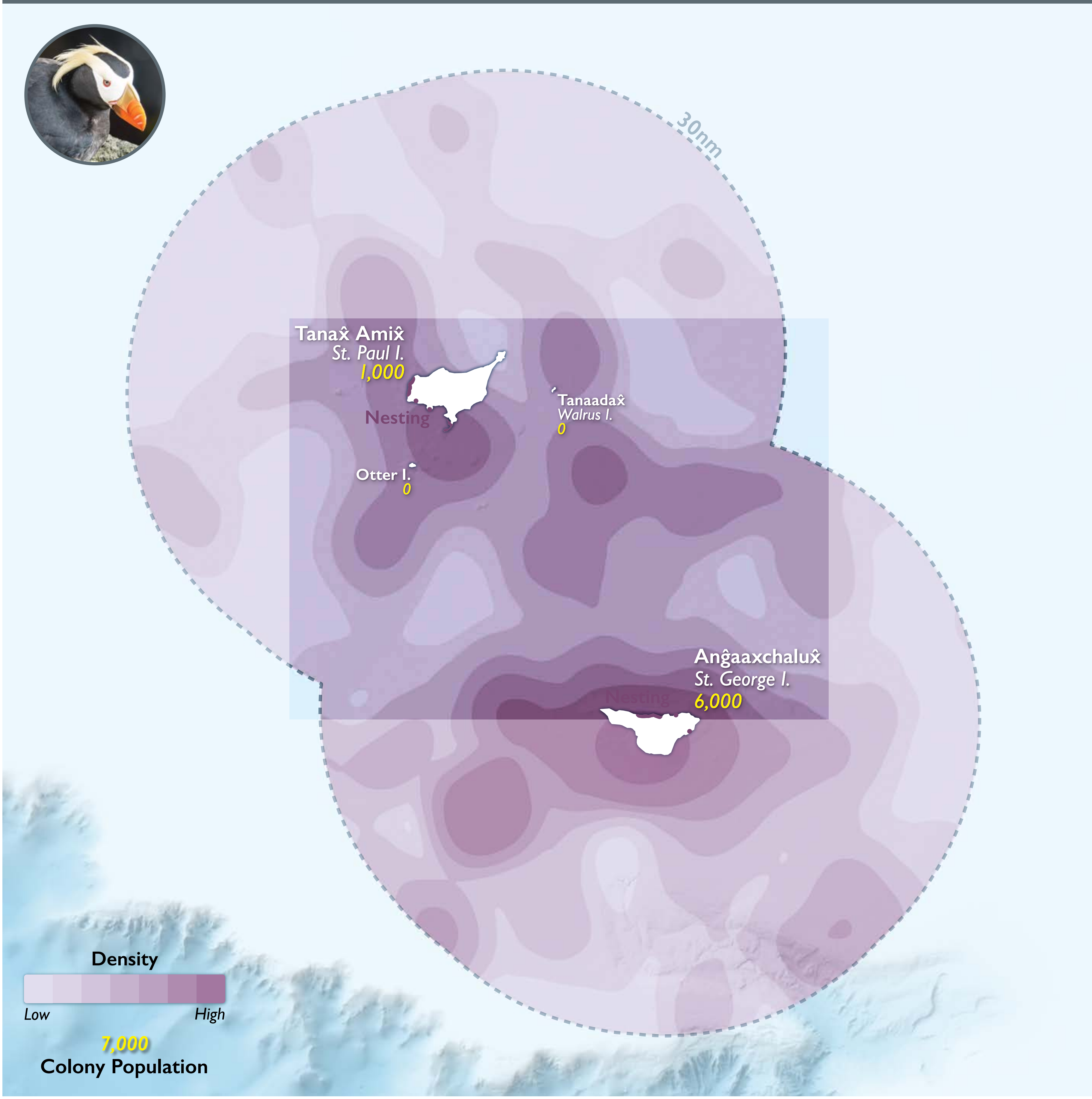
150NM

Tufted Puffin



30NM

Tufted Puffin



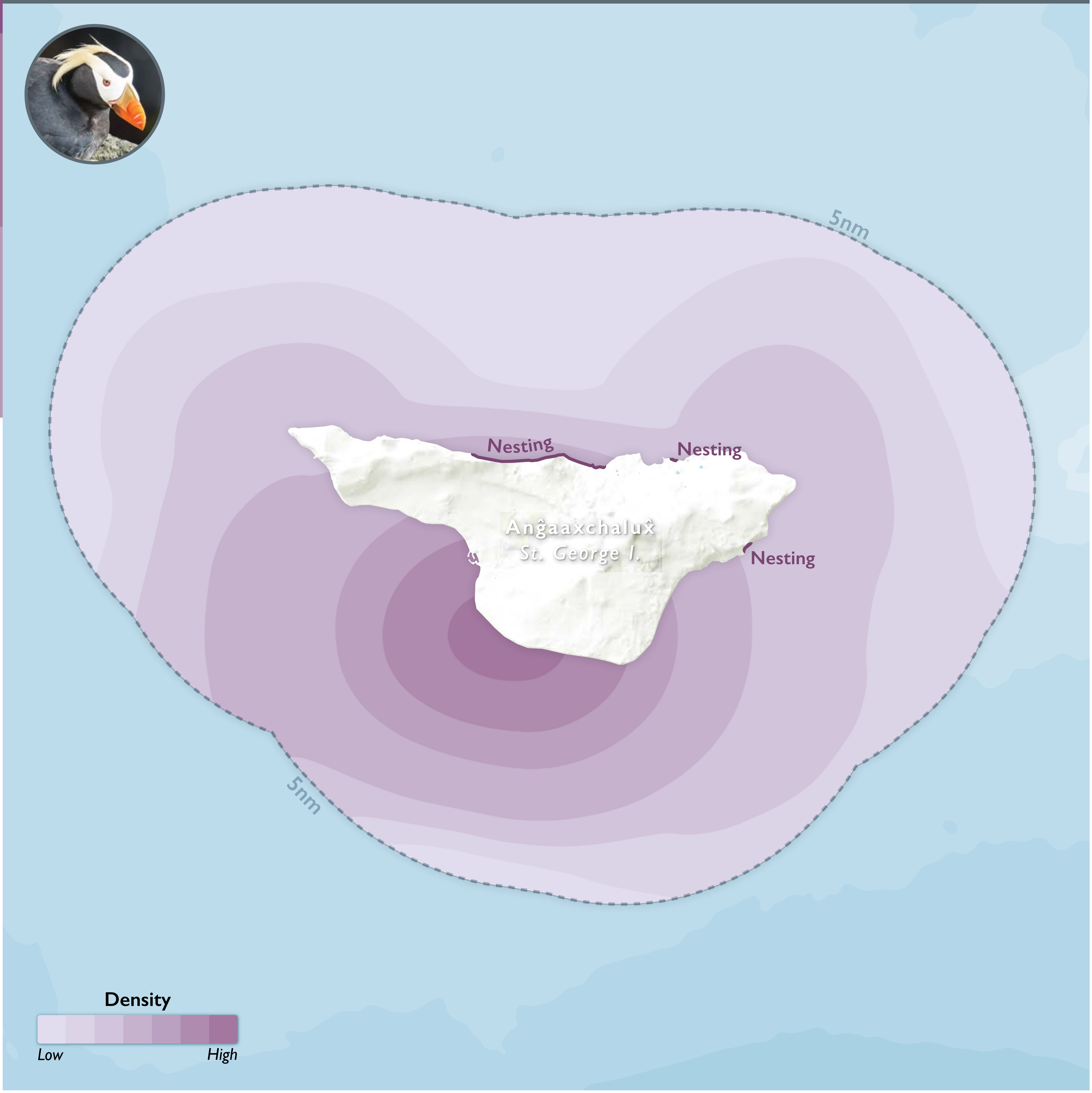
BIRDS

TUFTED PUFFIN

ST. GEORGE 5NM

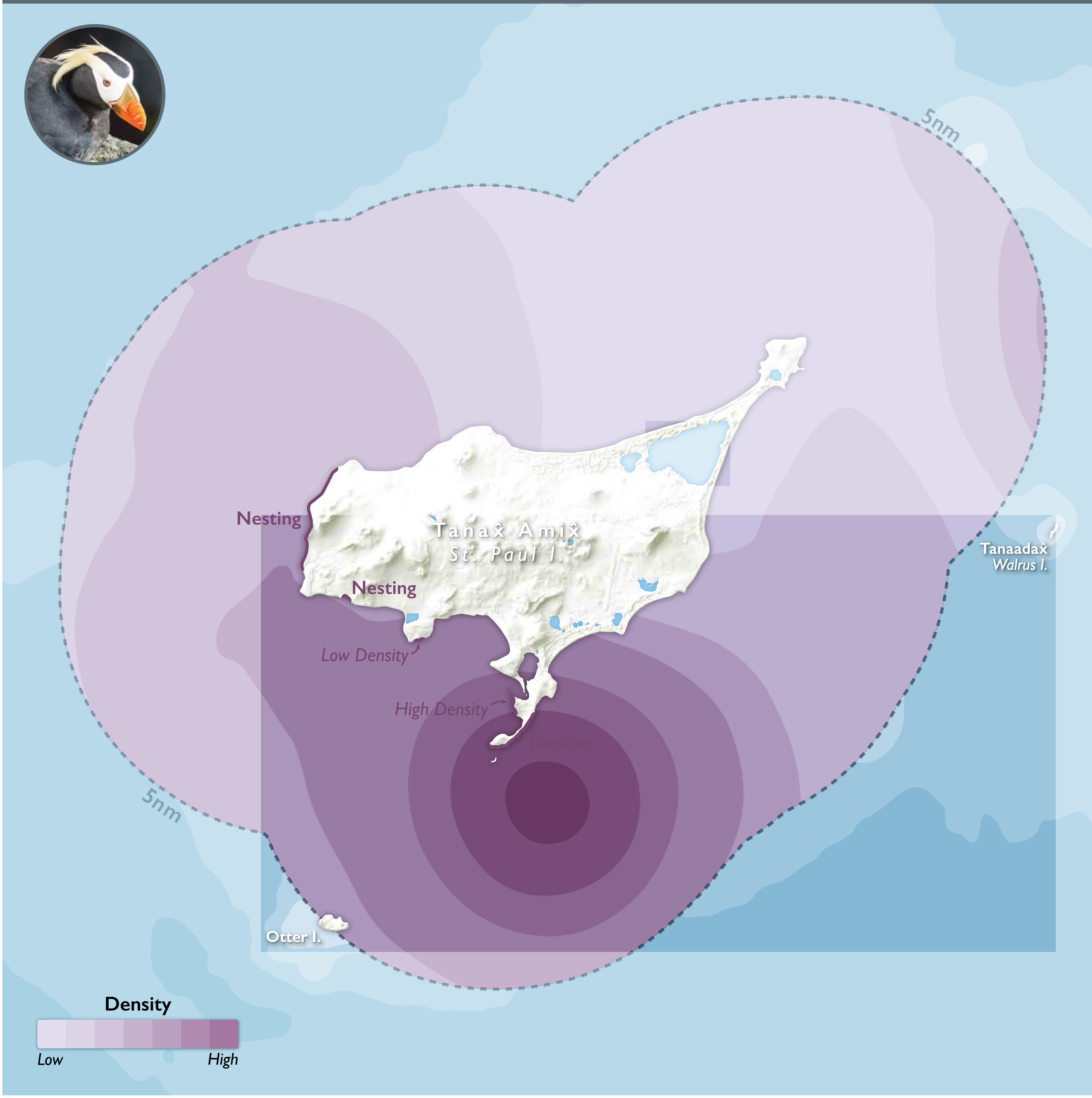
ST. GEORGE 5NM

Tufted Puffin



ST. PAUL 5NM

Tufted Puffin



Auklets

There are three species of Auklets (*Aethia* spp.) occurring in the Pribilof Islands. Auklets are enigmatic seabirds; they are characterized by elaborate facial feather ornamentation and complex courtship dances, yet their showiness is contrasted by their mystery. Most data on auklets come from breeding colonies that congregate on rocky islands and coastlines. However, these pelagic birds only come on land to breed, quickly returning to their marine habitat following the nesting season. Foraging behavior, migratory movements, and wintering range remain poorly known or unknown, yet are critical to conservation of these species.

Males and females appear identical, differentiated primarily by size. Auklets are characterized by dark plumages, contrasted with striking white eyes, generally red bills, and conspicuous ornamental facial plumes, which vary by species. The *Chuuchiiĝix̂* or Least Auklet (*Aethia pusilla*) has a knob on its bill and numerous bristly facial plumes that cluster around its eyes and forehead. The *Agaluuyax̂* or Parakeet Auklet (*A. psittacula*) is relatively drab with a single prominent white facial streak extending from just behind its eye to the back of its head. The *Kunugyux̂* or Crested Auklet (*A. cristatella*) is overall very dark, with a white streak extending from its eye toward the back of its head, and a prominent black puff of feathers curling over and beyond its bill. Elaborate facial patterns and plumes in both sexes are probably the result of sexual selection; birds with more prominent facial decoration are preferred by both sexes (Jones and Montgomerie 1992; Jones 1993). The particularly protruding feather plumes in *Kunugyun* have also been proposed as a sensory adaptation for navigating tight crevices in dark nesting burrows (Seneviratne and Jones 2008). Auklets are colonial breeders. *Kunugyun* and *Chuuchiiĝin* are more vocal and gregarious than *Agaluuyan* and colonies regularly include mixed *Aethia* and other seabird species. Where *Aethia* species overlap, there can be some competition for nest sites, with *Kunugyun* and *Agaluuyan* usually displacing the relatively tiny *Chuuchiiĝix̂* (Knudtson and Byrd 1982). However, the variation in sizes between these species also allows for niche differentiation into a range of nest cavity sizes.

Auklets do not build a nest, but instead lay their single egg directly on the substrate in cavities on rocky shorelines, talus slopes and rocky cliffs, with varying levels of bare and vegetated micro-terrain (Byrd et al. 1993; Byrd and Williams 1993; Hipfner and Byrd 1993; Jones 1993; Jones et al. 2001; Bond et al. 2013). The size of the cavity chamber and entrance vary by species size. Colonies of *Kunugyun* occur on both islands and mainland coastlines of Alaska and Russia; Parakeet and Least Auklets occur on islands in Alaska and also along certain mainland coastlines in Russia. In St. George, Least Auklets are commonly observed flying inland towards the rocky outcroppings along Ulakaia Hill, where they historically nested in the hundreds of thousands.

Auklets are agile divers that forage on the open ocean, using their wings to propel themselves underwater in pursuit of prey. *Kunugyun* and *Chuuchiiĝin* forage on marine zooplankton, preying on *Neocalanus* copepods and euphausiids (Bédard 1969b; Piatt et al. 1990; Troy and Bradstreet 1991; Byrd and Williams 1993; Jones 1993; Bond et al. 2013). *Agaluuyan* has a conical bill thought to be adapted to feeding on zooplankton and crustaceans, and even small fishes that cluster around jellyfish tentacles (Jones et al. 2001). However, in using this foraging tactic, *Agaluuyan* are also apparently susceptible to ingesting plastic particles that cluster around jellyfish and mimic prey items (Jones et al. 2001).

Auklet foraging focuses on areas where water currents bring prey items into greater concentration, and the species appear somewhat differentiated in their foraging microhabitats. *Agaluuyan* feed in turbulent tidal areas (Hunt et al. 1993; Hunt et al. 1998). *Kunugyun* and *Chuuchiiĝin* forage in deeper waters that are stratified, where upwelling brings prey to the surface (Haney 1991; Hunt et al. 1993; Jones 1993; Bond et al. 2013), but *Chuuchiiĝin* probably seek deeper concentrations of prey (Jones 1993).

> "There used to be 250-260 thousand auklets going up to Ulakaia Hill, but the growth of grass and moss that now grows over that area has taken away their habitat. It's been in the last 40 or so years, in my lifetime."
>
> ~ M. Merculieff Sr.

M. Burcham

In addition to their white eye plumes, and distinctive feather crests, Crested Auklet's bill plates—temporary structures that surround their beak during mating season—are the first-known bird part (besides feathers) that fluoresce. The plates don't just reflect light the way colored surfaces do, but actually change its wavelength (adapted from Audubon.org).

C. Demienteff

The Parakeet Auklet has the widest distribution of all the Alaskan auklets. Their unusual bill structure is probably an adaptation for handling slimy gelatinous prey, like jellyfish, although it is unclear exactly how the bill is used (adapted from allaboutbirds.org).

Colonies of Least Auklets on St. Paul Island have declined in recent years, but the underlying causes of their decline remain uncertain.

Paviilax

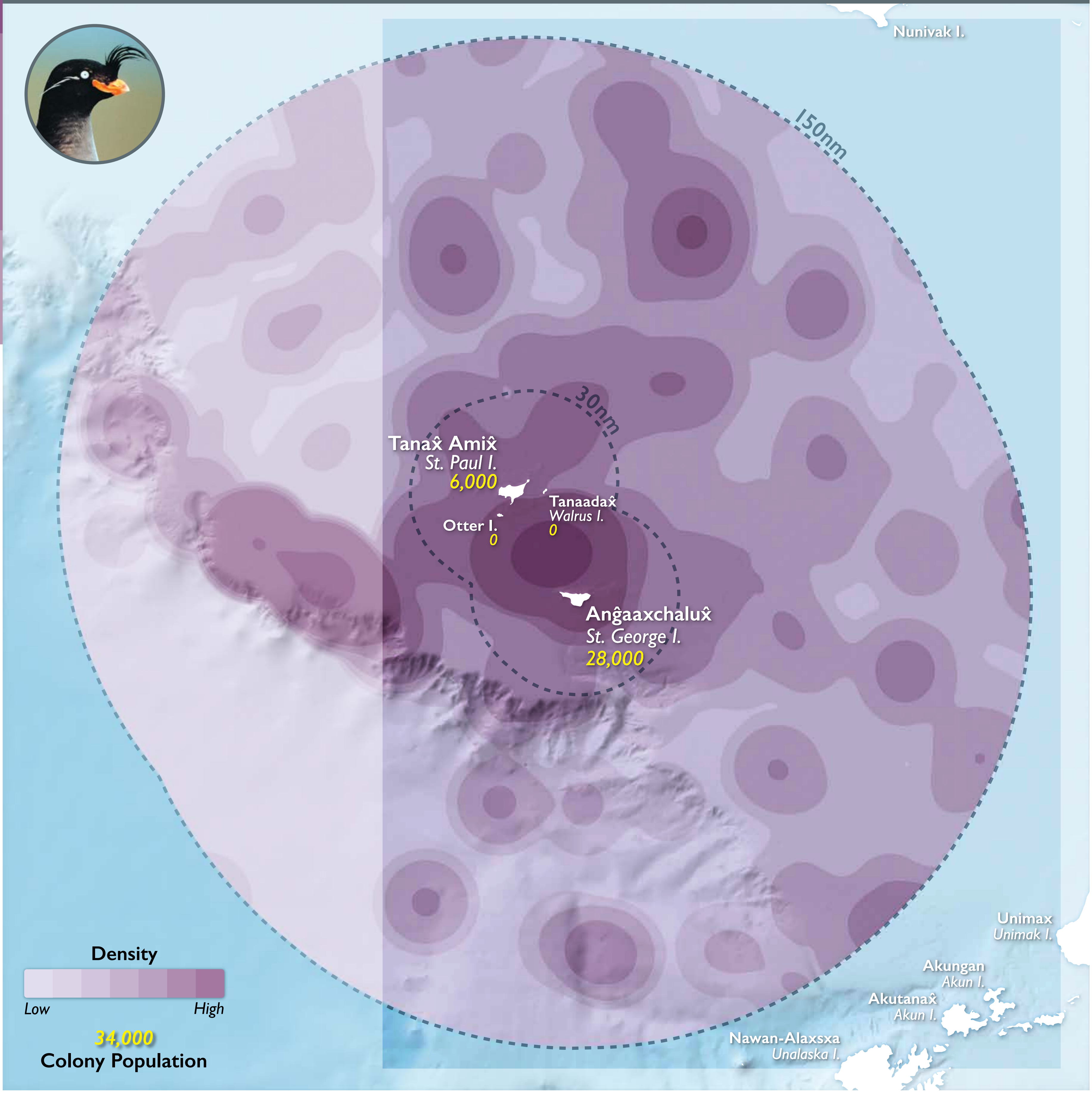
BIRDS

CRESTED AUKLET

150NM

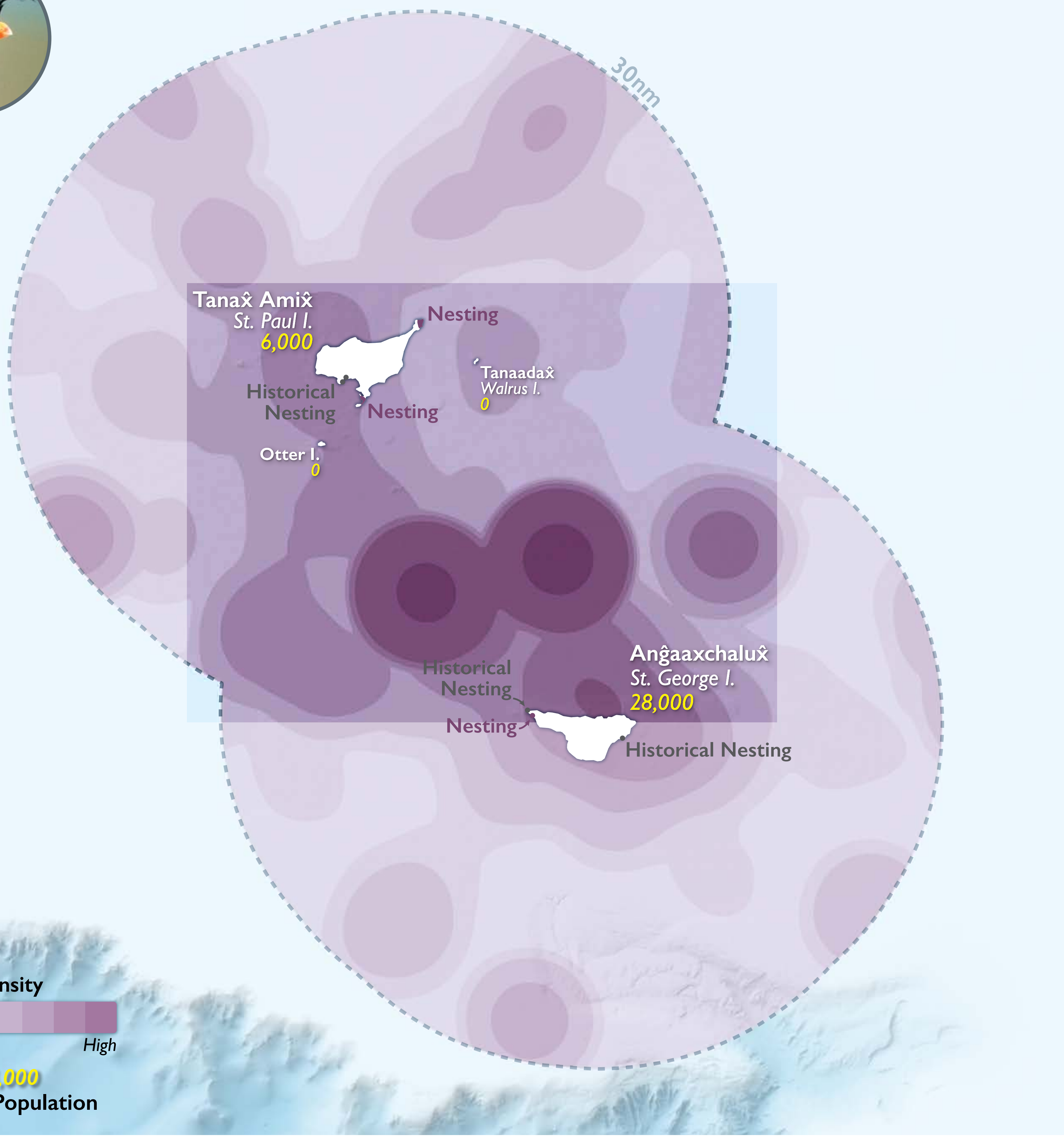
150NM

Crested Auklet



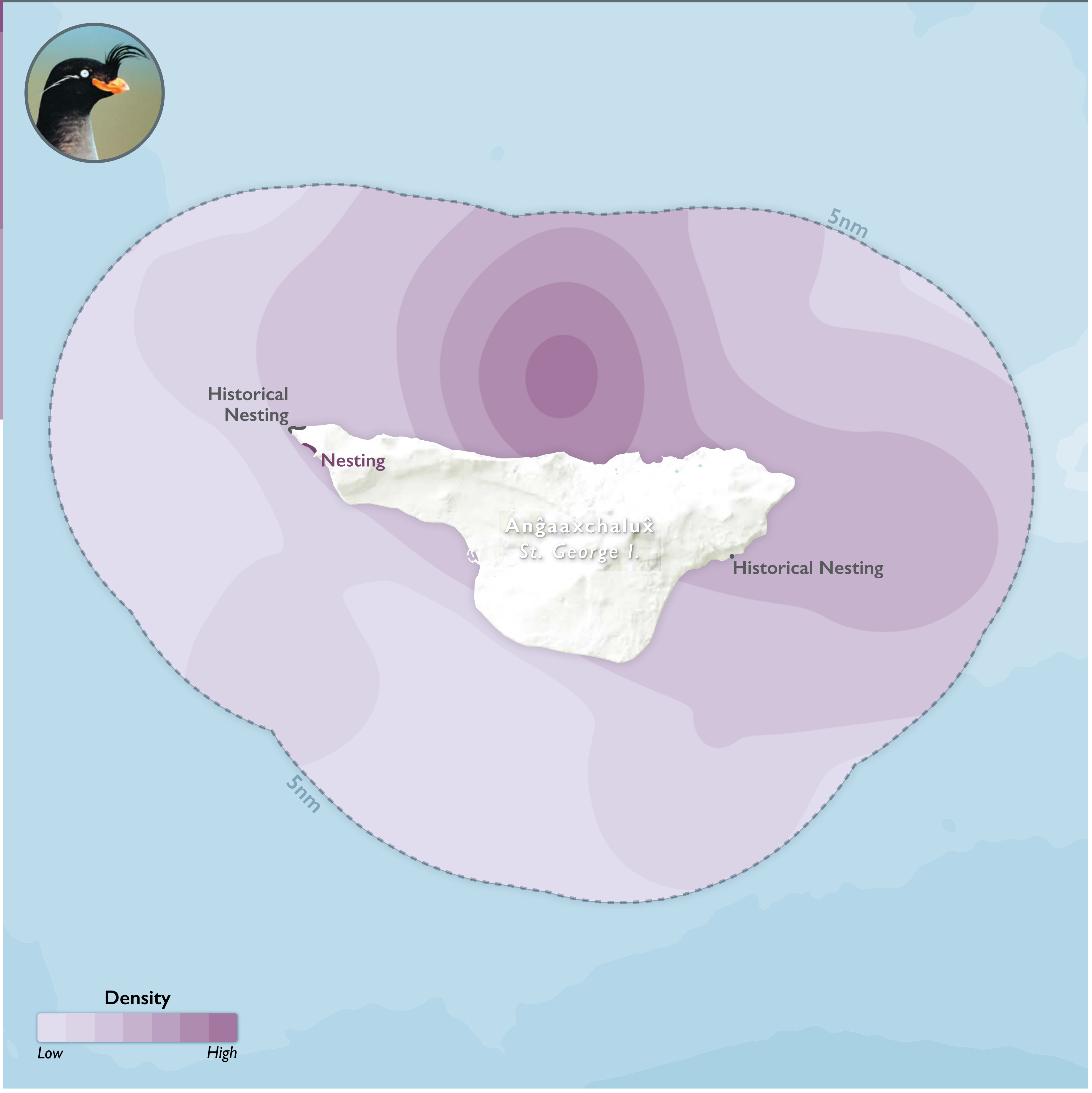
30NM

Crested Auklet



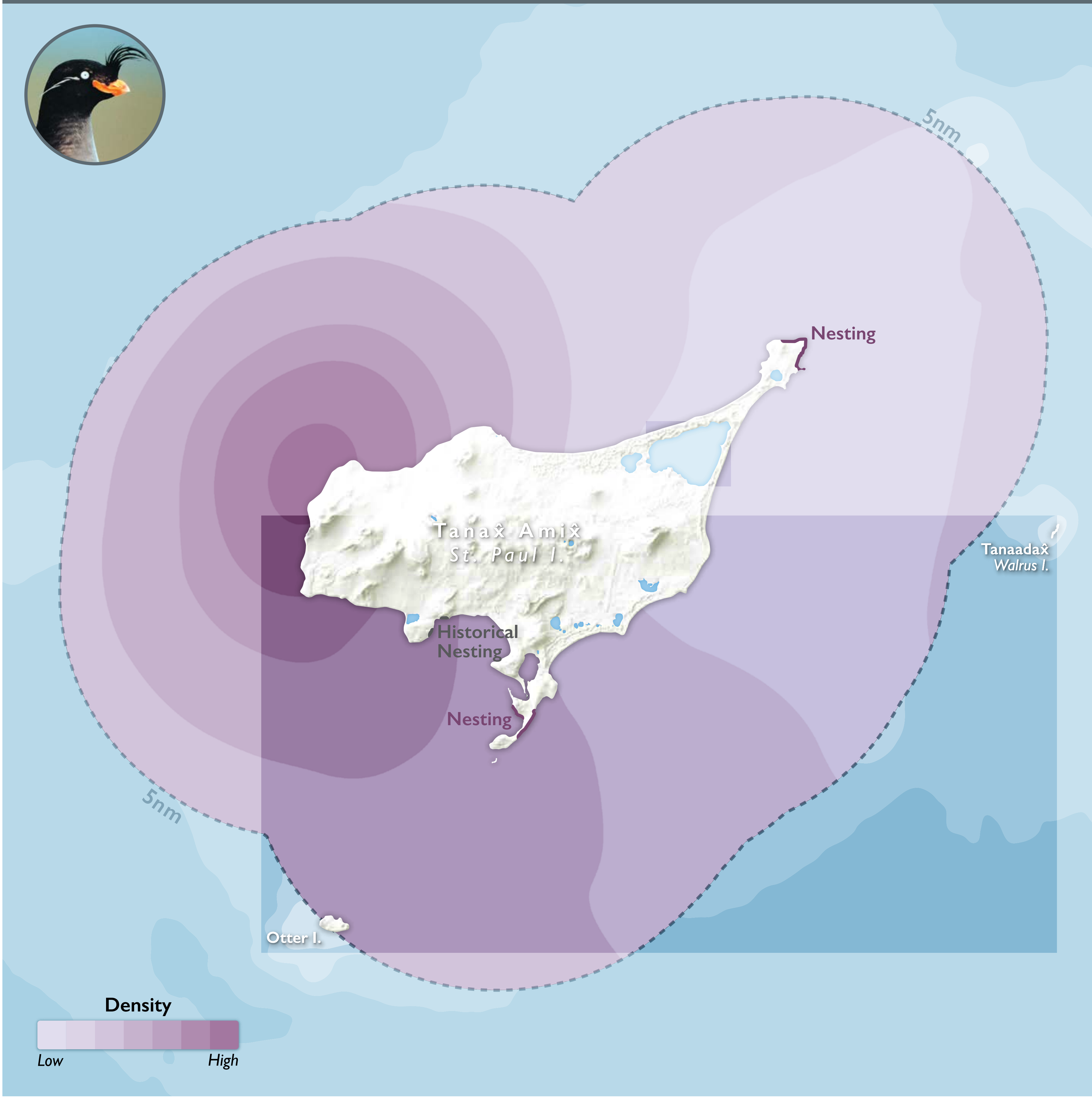
ST. GEORGE 5NM

Crested Auklet



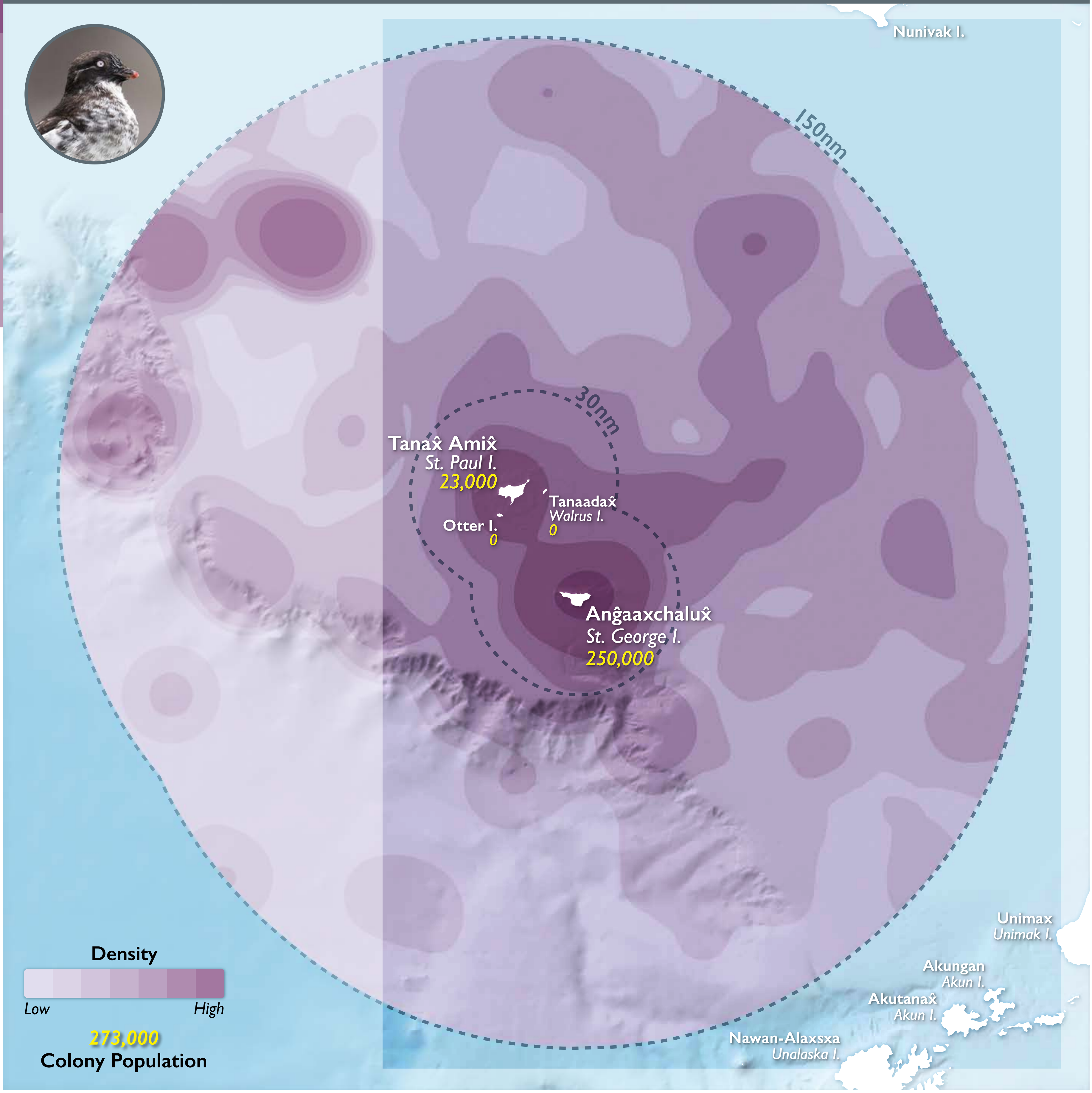
ST. PAUL 5NM

Crested Auklet



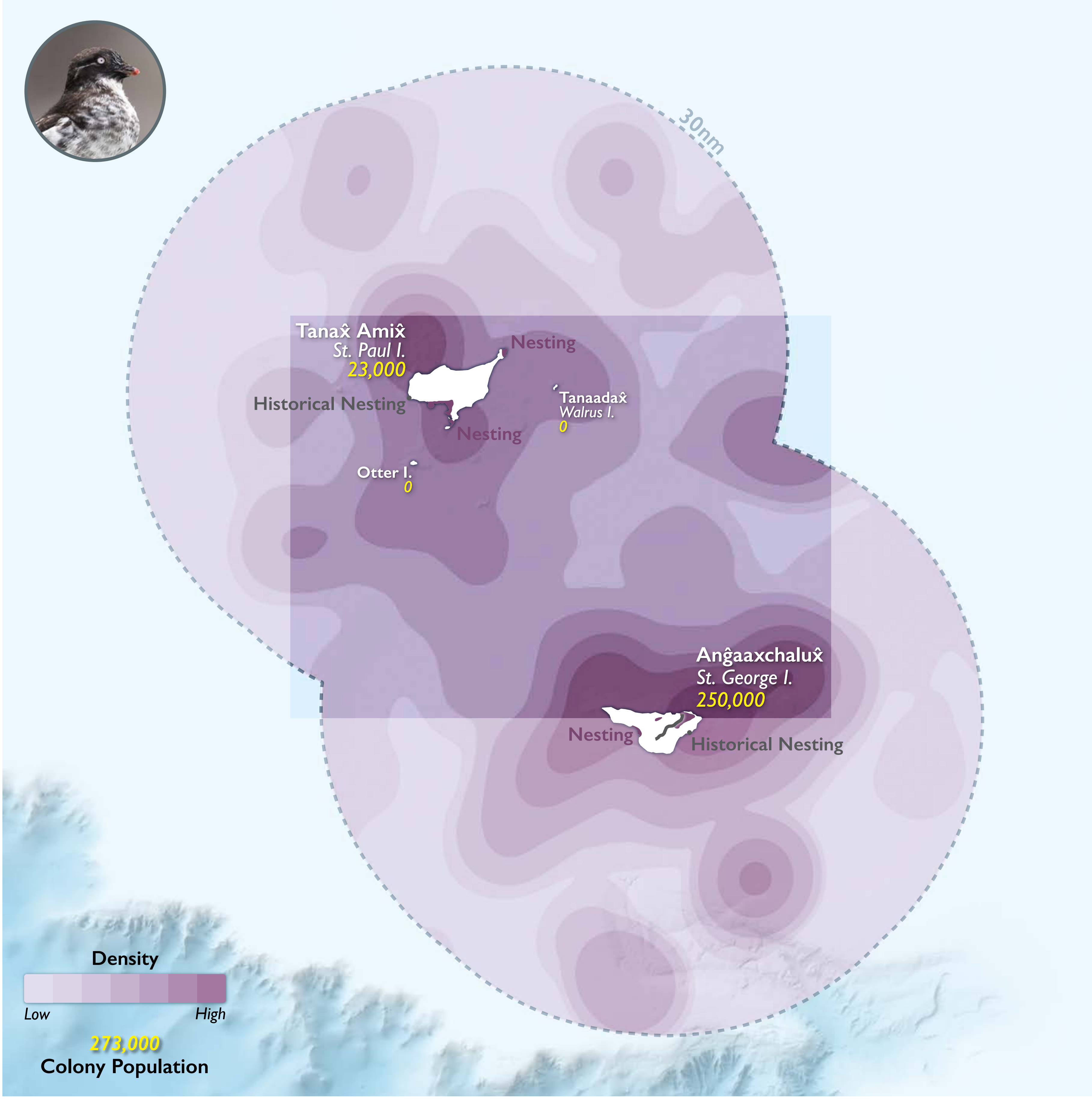
150NM

Least Auklet



30NM

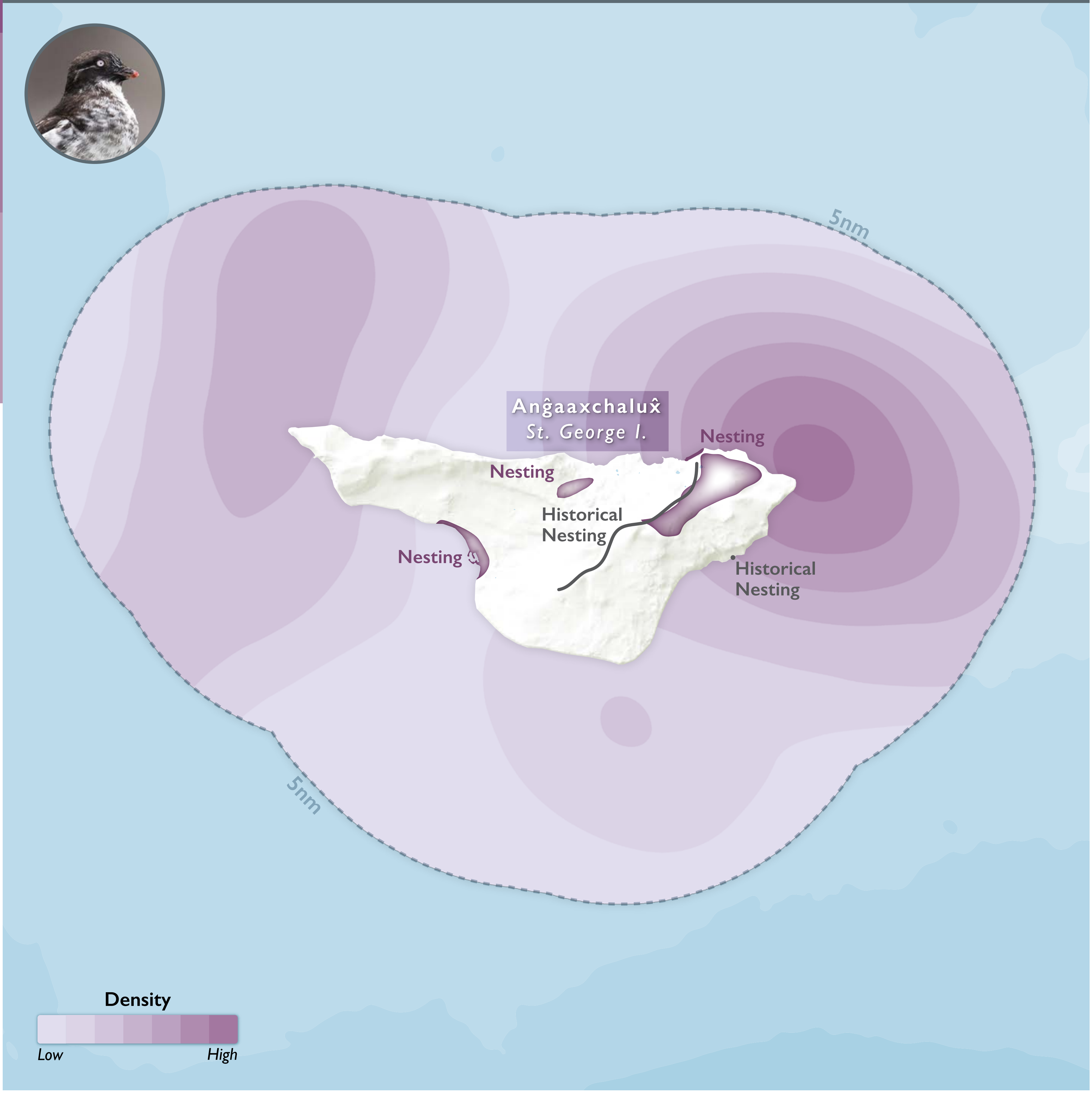
Least Auklet



ST. GEORGE 5NM

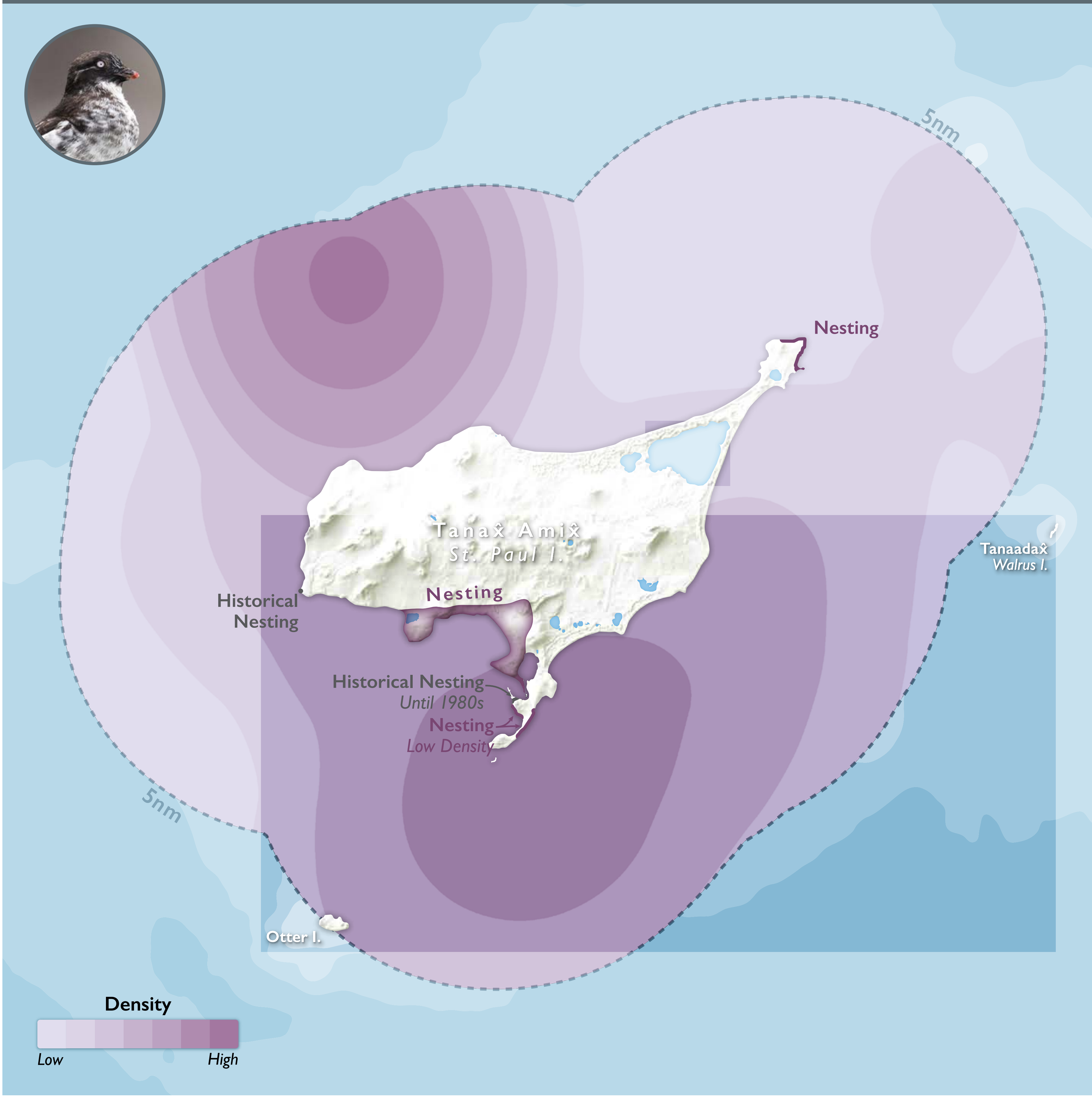
Least Auklet

CITY of ST GEORGE
ALEUT COMMUNITY OF ST. PAUL TRIBAL GOVERNMENT
Audubon | ALASKA



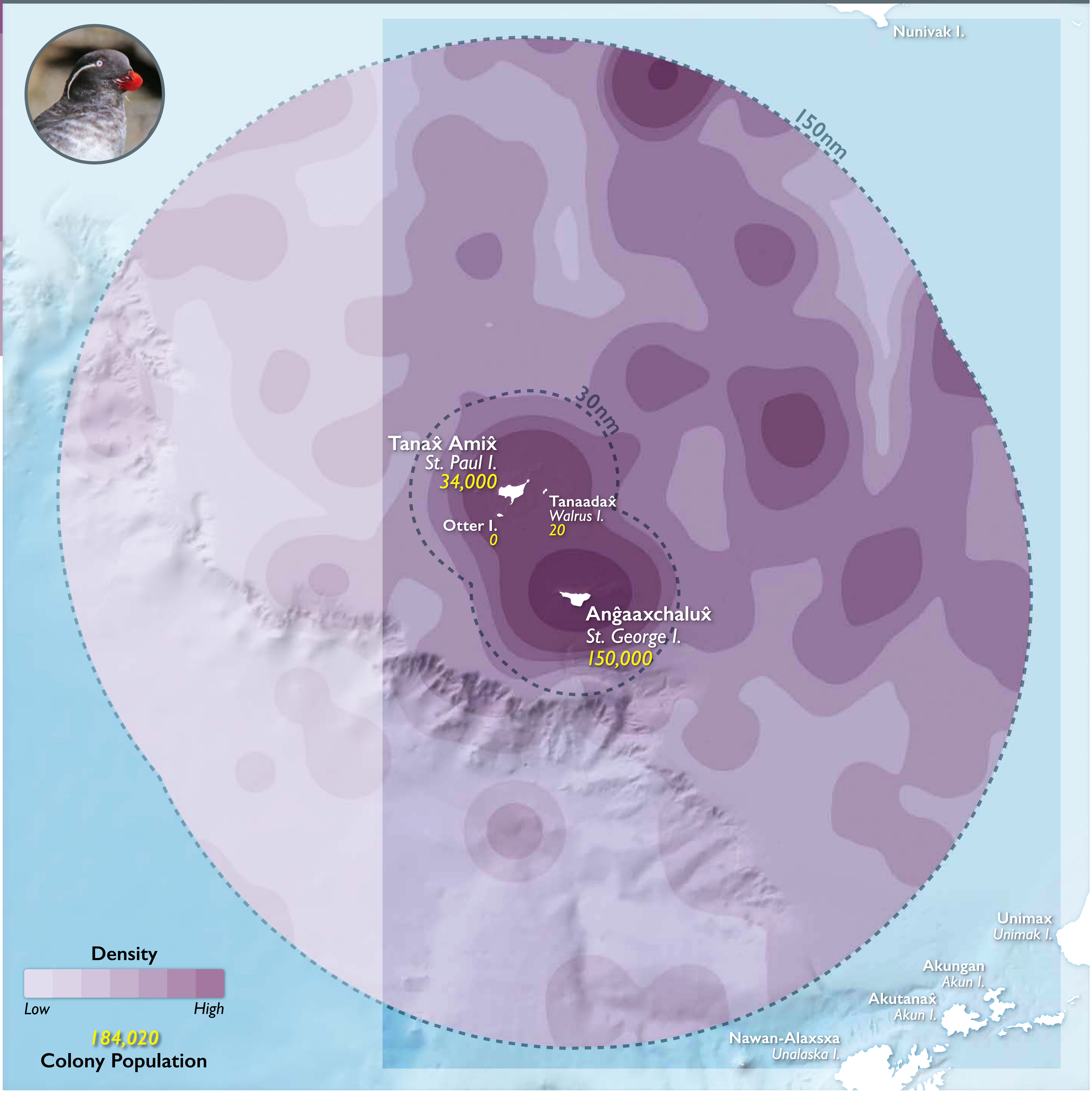
ST. PAUL 5NM

Least Auklet



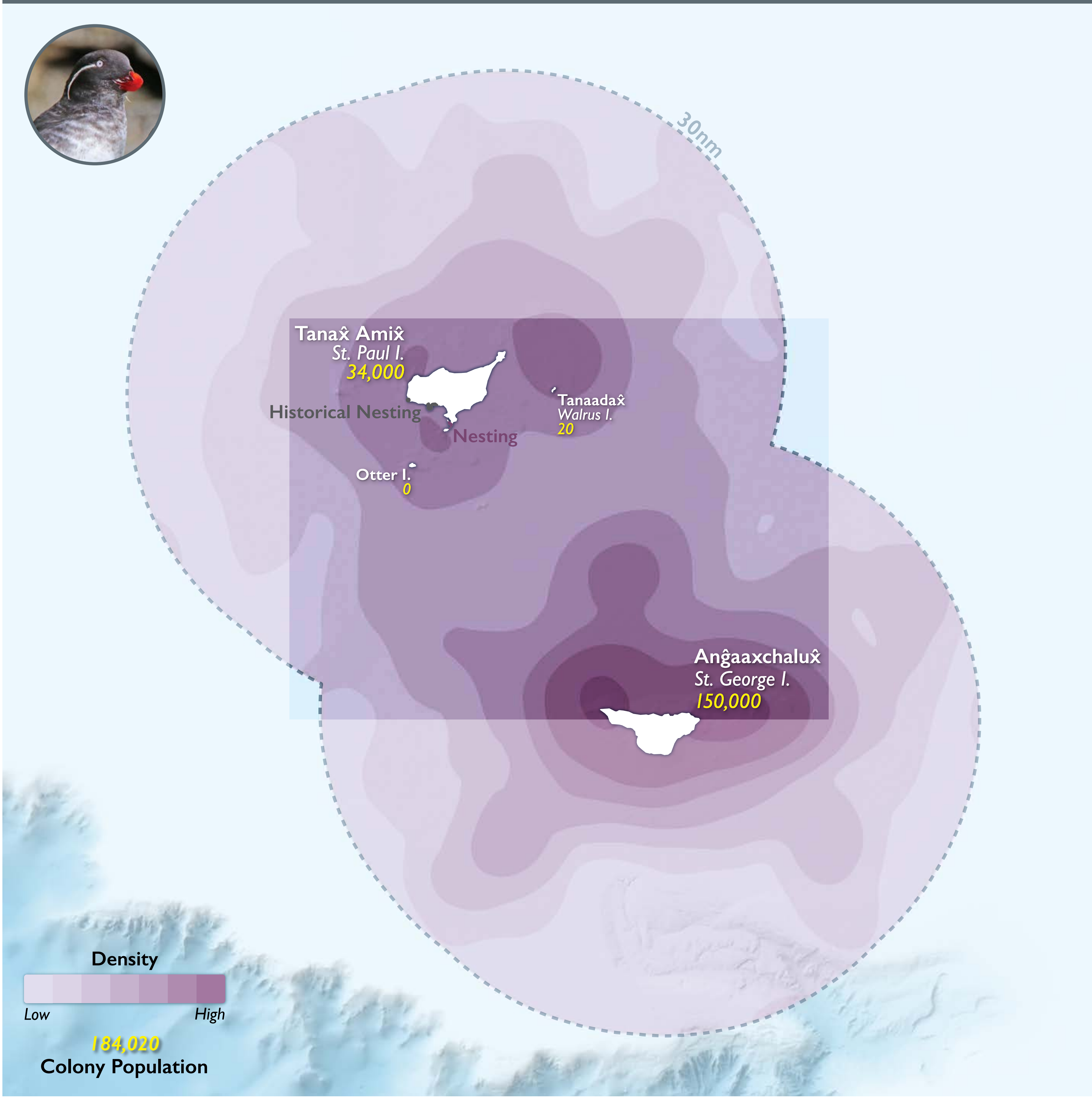
150NM

Parakeet Auklet



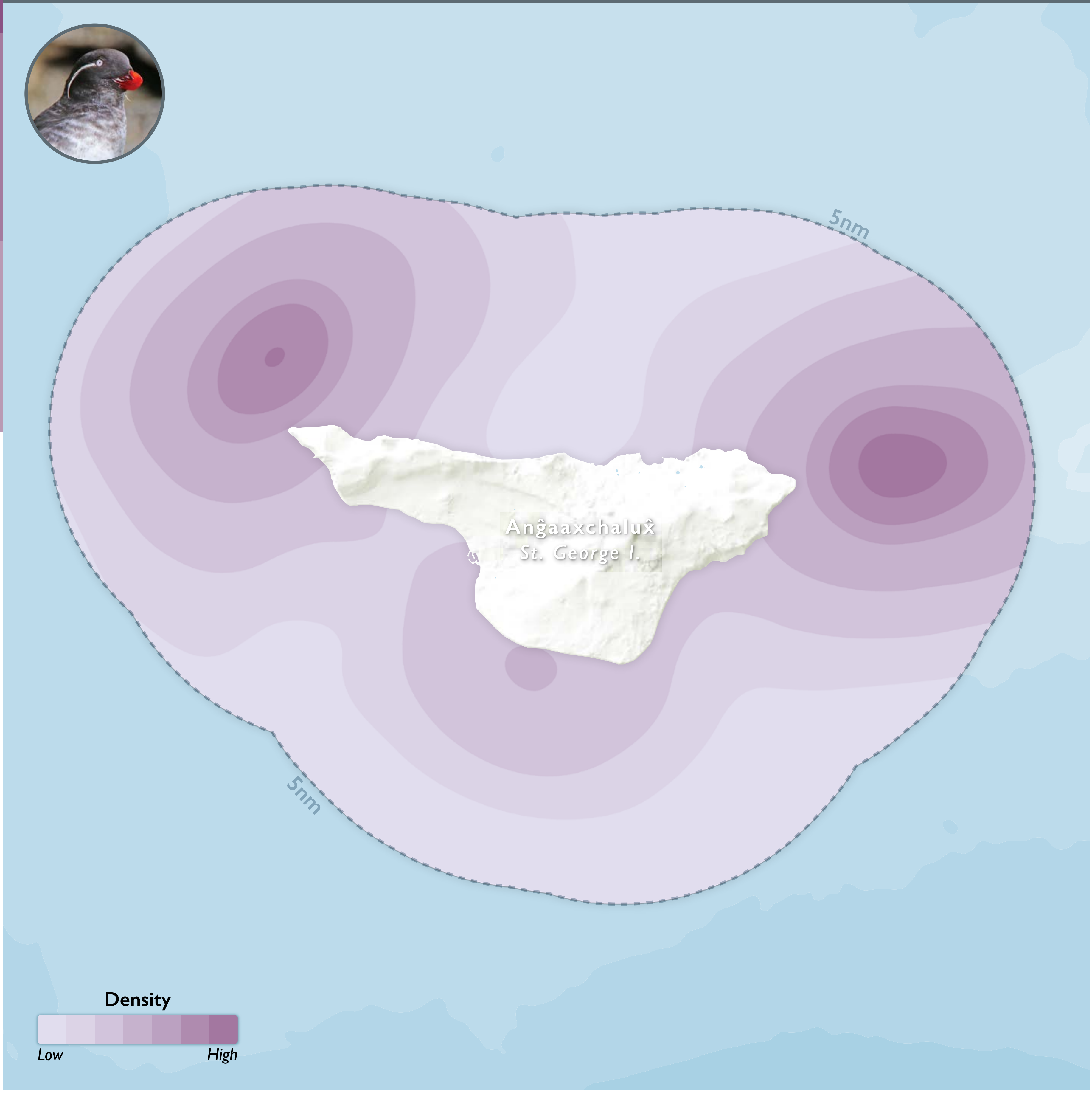
30NM

Parakeet Auklet



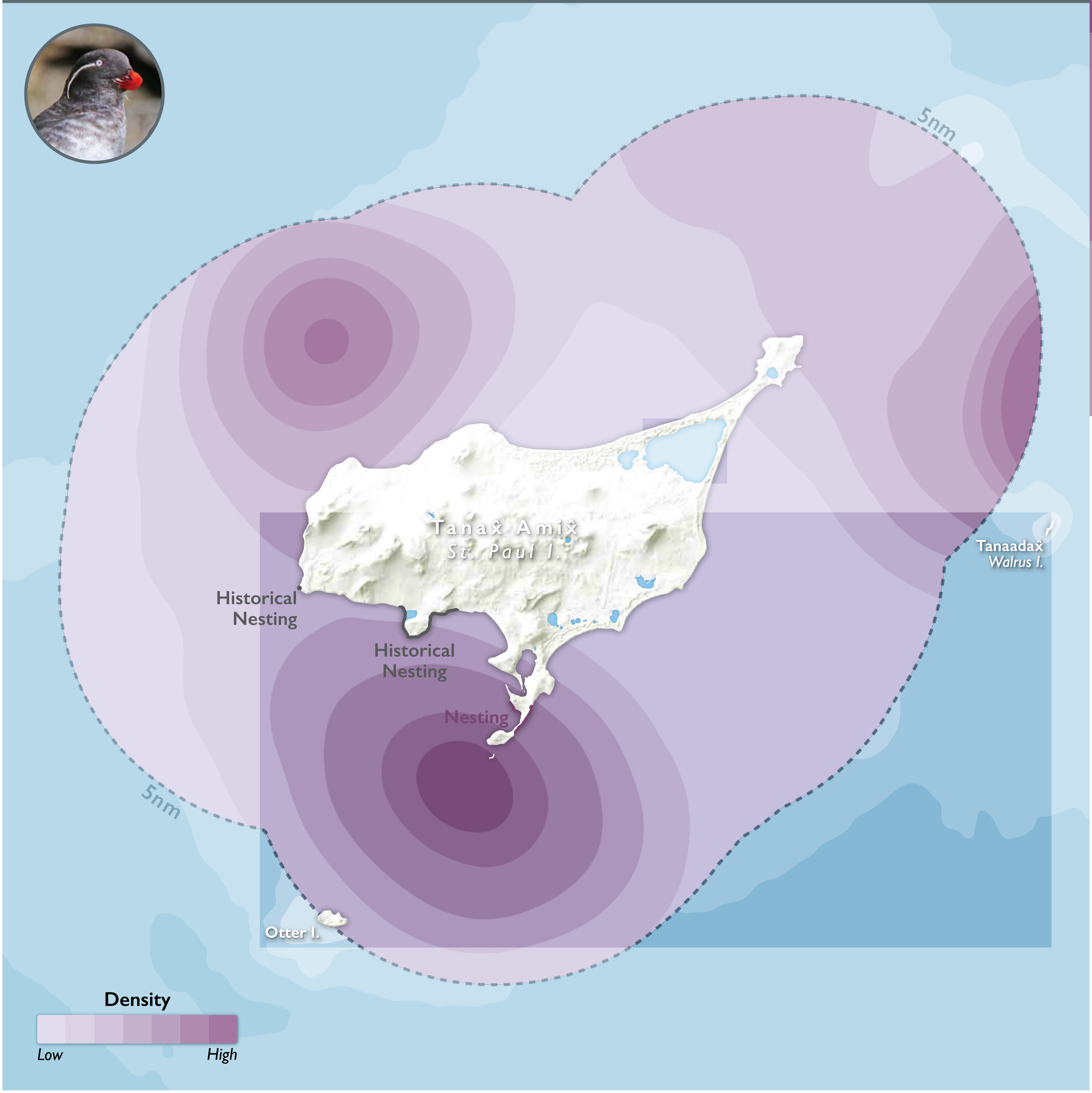
ST. GEORGE 5NM

Parakeet Auklet



ST. PAUL 5NM

Parakeet Auklet



Albatrosses

As ponderous on land as they are graceful in the air, Albatrosses (*Phoebastria* spp.) are regular visitors to Alaska waters. In the late 1800s, global populations were estimated to be in the hundreds of thousands to millions (Hasegawa and DeGange 1982), and these global wind travelers were reportedly seen and eaten regularly by local communities in the Bering Sea region (Nelson et al. 1887; Gabrielson and Lincoln 1959; Murie 1959; Yesner and Aigner 1976). However, plumage hunters decimated the breeding colonies in Japan at the turn of the century (Hasegawa and DeGange 1982), and by the 1950s, ornithologists in Alaska were suggesting that the birds were nearly extinct or extinct (Gabrielson and Lincoln 1959; Murie 1959). While still numerically rare, populations are climbing back from precipitously low numbers (Kuro-o et al. 2010). Since the early 2000s, sightings have been increasing in Alaska (Kuletz et al. 2014). Aside from their breeding grounds, few other regions are as important to albatrosses, especially the Short-tailed Albatross (*Phoebastria albatrus*), as the upwelling waters in the Bering Sea (Piatt et al. 2006; Suryan et al. 2007). While not an Arctic or subarctic breeder, many Short-tailed Albatrosses spend their short time away from the breeding colony foraging in the productive waters on either side of the Aleutian Islands, and fishermen in the Pribilof Islands commonly report sightings of albatrosses (usually observed as one individual) offshore near fishing grounds.

Albatrosses are monogamous with about an eight-month breeding cycle (U.S. Fish and Wildlife Service 2008). Like all albatrosses, the age of first breeding is quite delayed, and for Short-tailed Albatrosses, the average is six years (Finkelstein et al. 2010). Birds begin arriving at breeding colonies in eastern Asia in early October, and successful breeders and fledglings leave the islands in late May to June (Hasegawa and DeGange 1982; McDermond and Morgan 1993).

J. Schoen

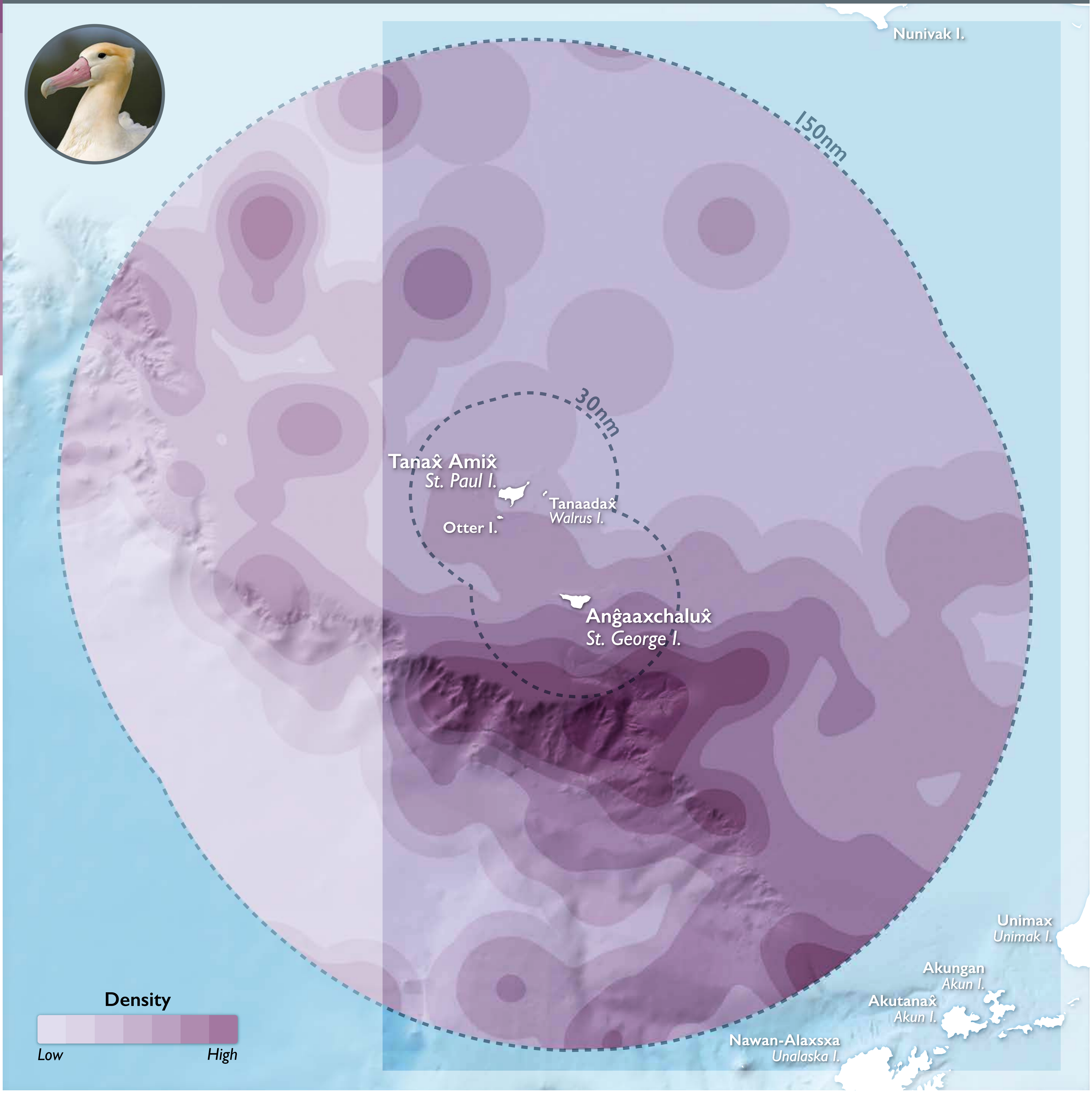
Albatrosses are a rare sight around the Pribilof Islands but local fishermen are always delighted to occasionally sight single individuals offshore.

Short-tailed Albatross were driven almost to extinction in the early 20th century, therefore sitings are rare today. Halibut fishers around the Pribilof Islands are often lucky to catch sight of these giant seabirds when they are out fishing.

K. Paleckova / Audubon Photography Awards

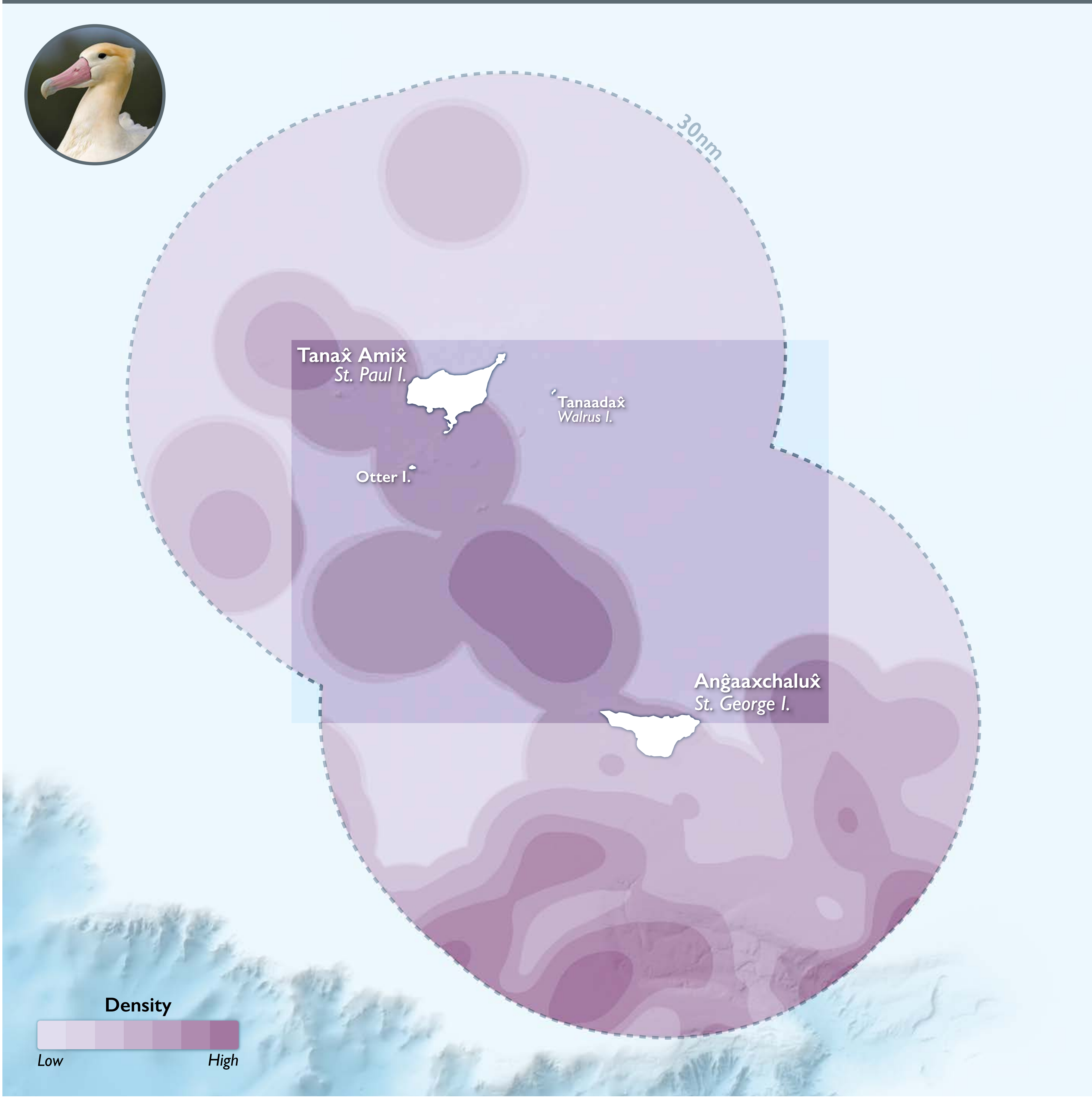
150NM

Total Albatrosses



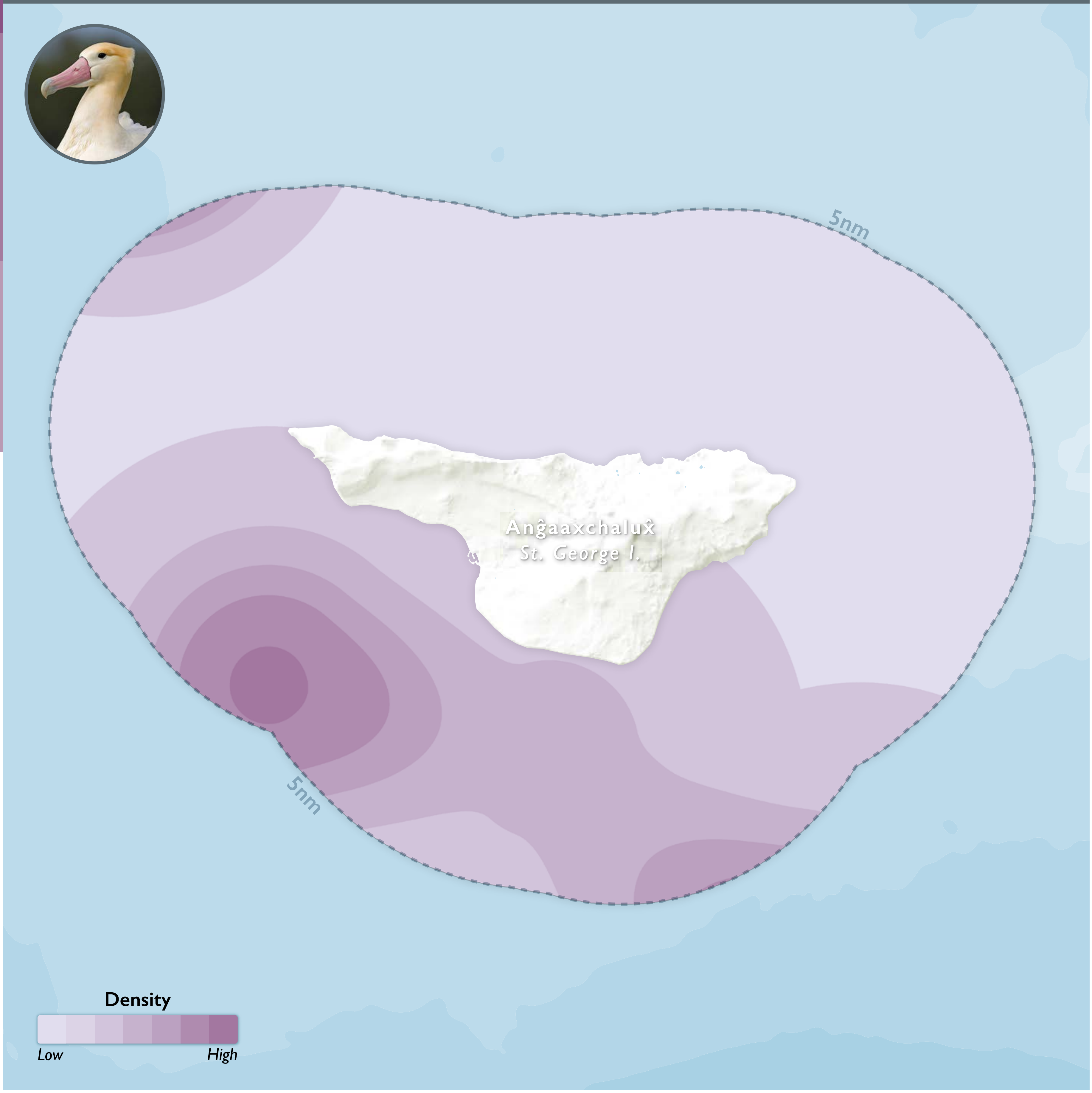
30NM

Total Albatrosses



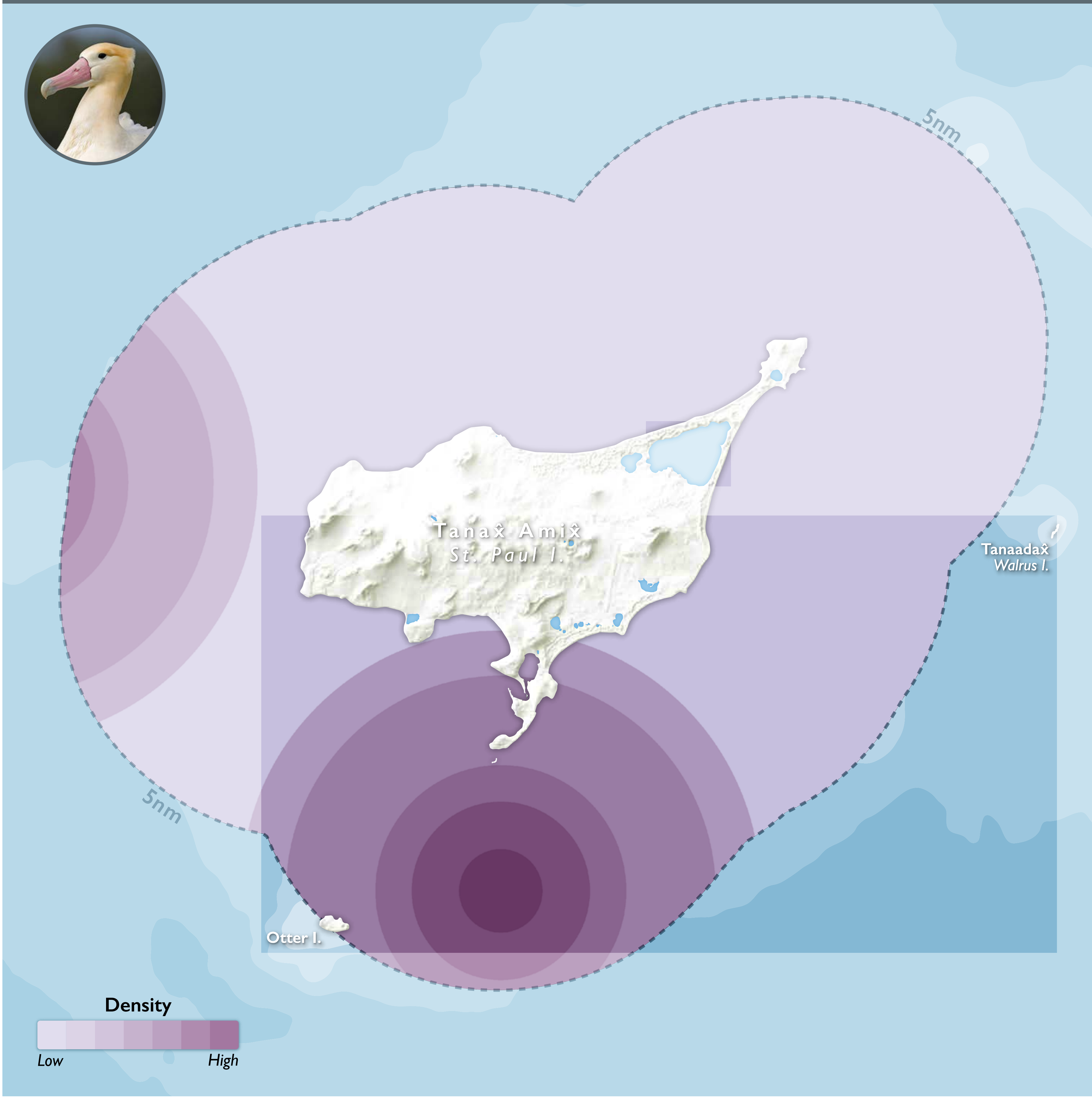
ST. GEORGE 5NM

Total Albatrosses



ST. PAUL 5NM

Total Albatrosses



Shearwaters

Short-tailed (*Ardenna tenuirostris*) and Sooty (*A. grisea*) Shearwaters belong to the family of birds known as Procellariidae that includes petrels and fulmars. Combined, Short-tailed and Sooty Shearwaters make up one of the most abundant pelagic bird taxa in North Pacific waters (Schneider and Shuntov 1993; Shuntov 2000) and are abundant on the Pribilof Islands. They also travel among the farthest distance of any bird that comes to Alaska, averaging 36,000–40,000 miles (59,000–64,000 km) per year (Shaffer et al. 2006; Carey et al. 2014). Both species arrive in Alaska in late April and early May and leave about 150 days later, in mid-September to early October (Shaffer et al. 2006; Carey et al. 2014). These global ocean movements allow Sooty and Short-tailed Shearwaters to breed in the Southern Hemisphere when primary productivity is higher than in the Northern Hemisphere, then move to North Pacific waters for foraging when primary productivity surpasses productivity in the southern latitudes—a strategy that has been described as "the pursuit of an endless summer" (Shaffer et al. 2006; Carey et al. 2014).

Major food items for both species include squid, fishes, and various crustaceans (Schneider and Shuntov 1993; Minami et al. 1995; Weimerskirch and Cherel 1998). In a diet comparison of the two species from the western North Pacific, Sooty Shearwaters ate more fish and squid while Short-tailed Shearwaters fed more on zooplankton (Minami et al. 1995). In the Bering Sea, including shearwaters foraging around the Pribilof Islands, euphausiids are a major prey item for Short-tailed Shearwaters (Murie 1959; Schneider and Shuntov 1993; Hunt et al. 1996).

While shearwaters breed in the southern hemisphere, they overwinter in the northern hemisphere. Rafts of shearwaters can be seen offshore of the Pribilof Islands each summer.

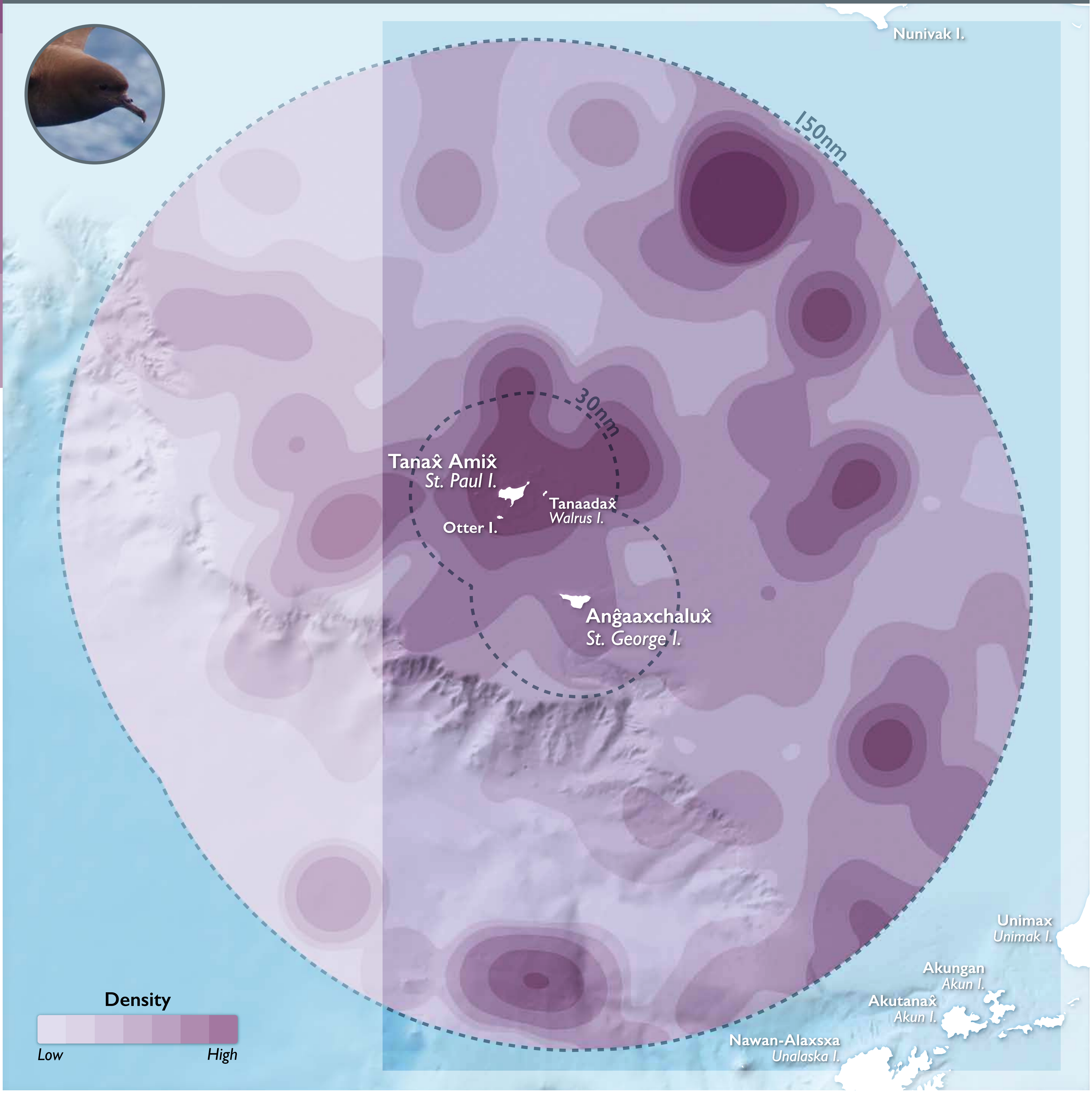
"Many of these birds, such as murres, kittiwakes, parakeet auklets, sooty shearwaters and many others, travel hundreds or thousands of miles from wintering habitat, making our seabird population remarkably diverse and globally significant."

~ Patrick Pletnikoff

M. Baird

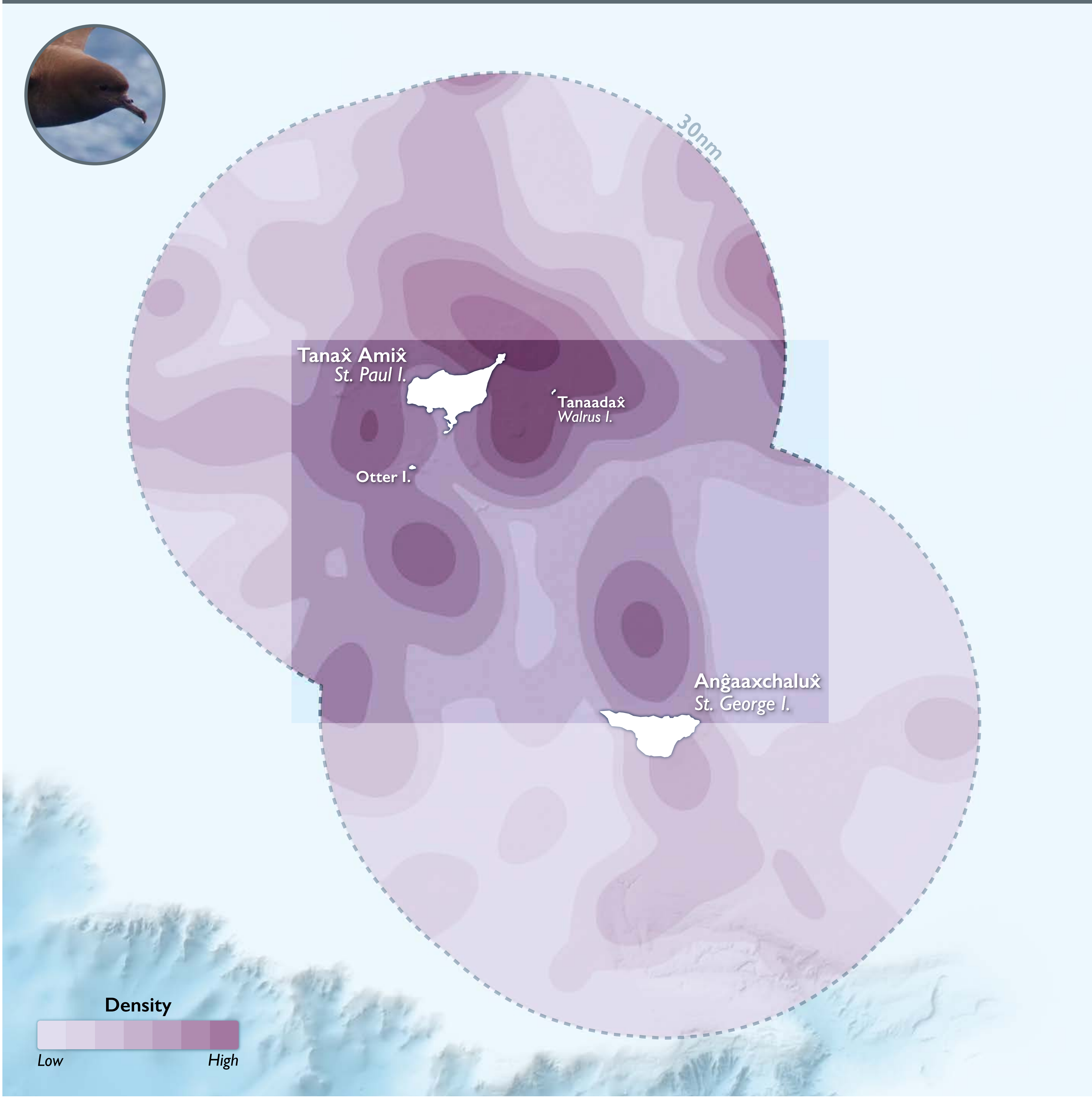
150NM

Total Shearwaters



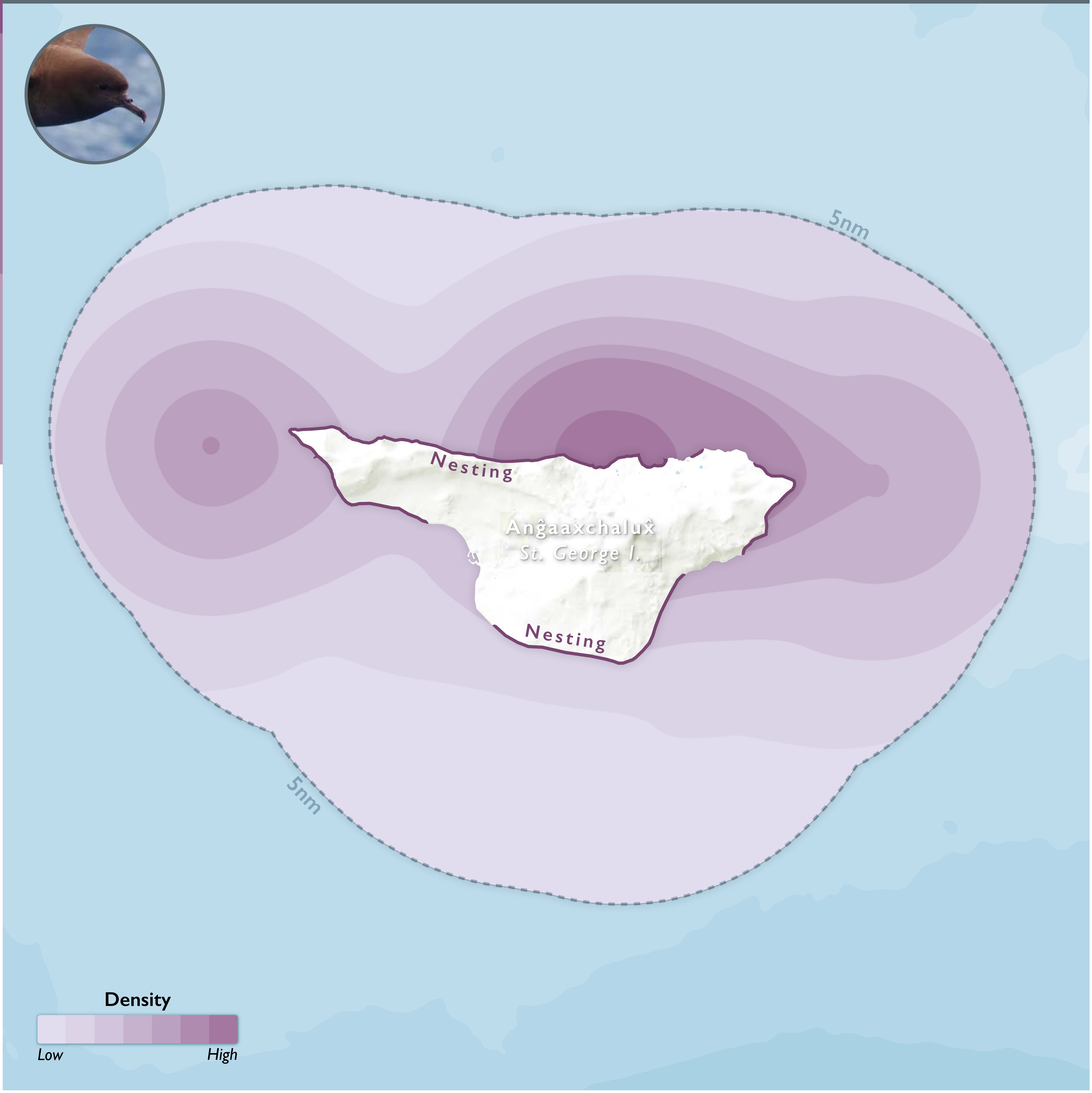
30NM

Total Shearwaters



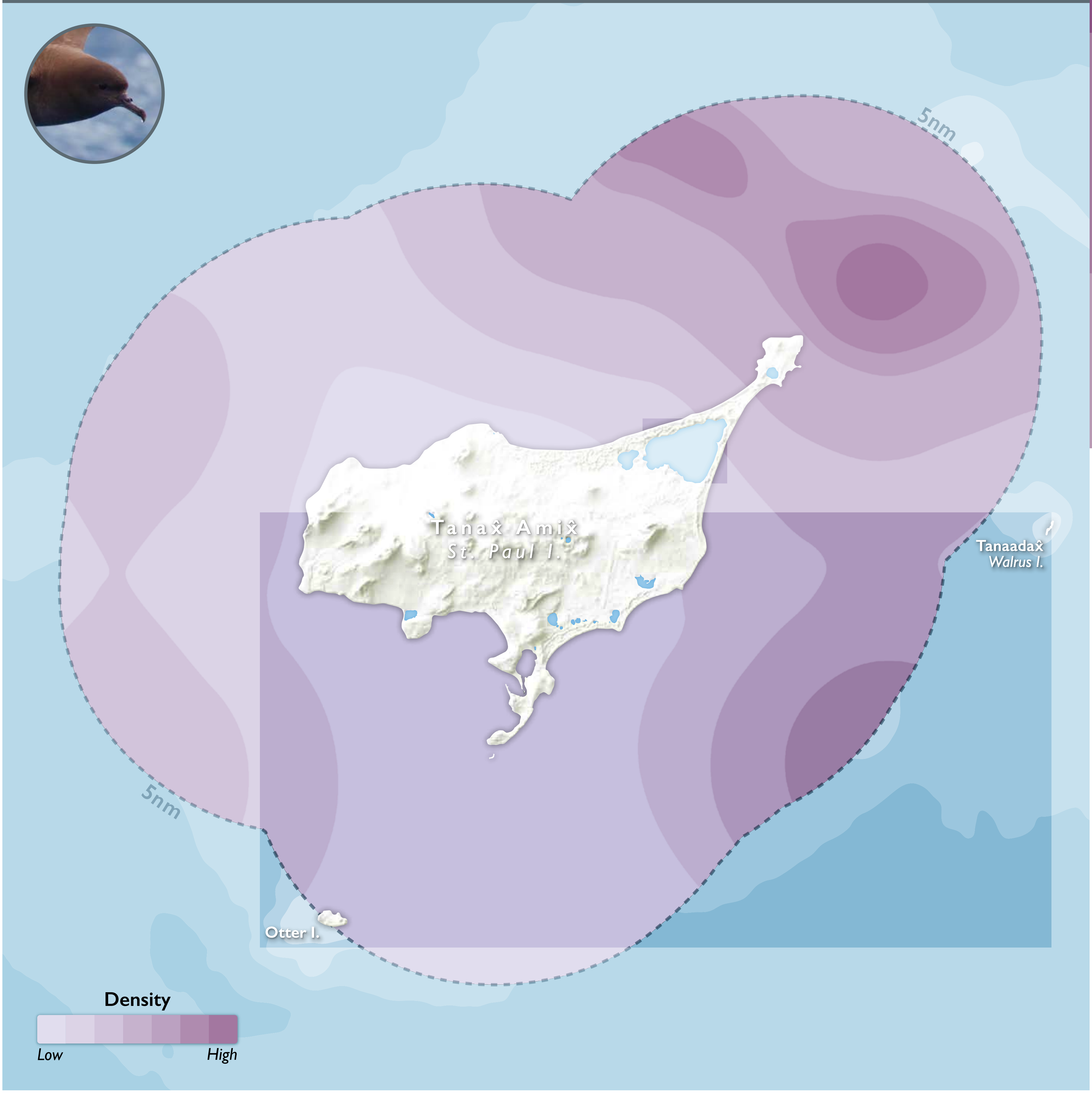
ST. GEORGE 5NM

Total Shearwaters



ST. PAUL 5NM

Total Shearwaters



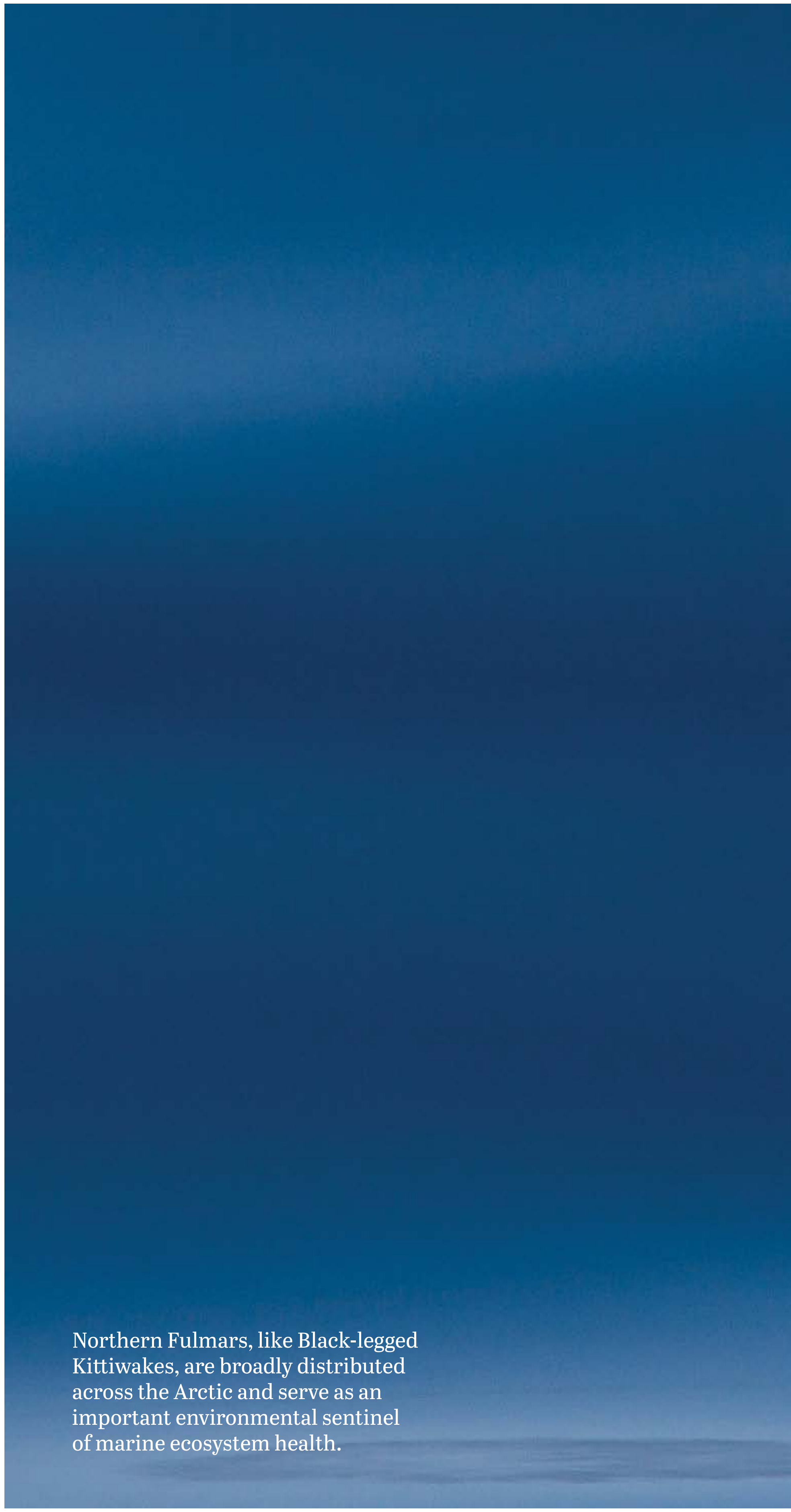
Northern Fulmar

Saayax̂, the Northern Fulmar (*Fulmarus glacialis*) belongs to the family of birds known as Procellariidae that includes petrels and shearwaters. Fulmars occur in one of two color morphs: a light one, with white head and body and gray wings and tail, and a dark one which is uniformly gray. *Saayan* are one of the longest-lived birds, with a life span of over 30 years. *Saayan* breed on open sea cliffs where soil is present to make a shallow scrape. Mating pairs produce a single egg and take turns incubating for 6-8 weeks. *Saayan* do not breed on the Pribilof Islands, but similar to shearwaters, occupy the region during the summer months for foraging.

Fulmars produce a stomach oil made up of wax esters and triglycerides that is stored in the proventriculus, a part of the bird's digestive system (Double 2003). The stomach oil can be used as an energy rich food source for chicks and for the adults, or sprayed out of their mouths as a defense against predators. Fulmars feed on crustaceans, small squid, marine worms, and fish at or just below surface of water while swimming, and can often be seen picking at jellyfish.

Elders on both St. Paul and St. George have cited shifting prey distributions and a 'lack of food' as the reason behind declining populations.

(St. George: M. Merculief Sr. and P. Pletnikoff;
St. Paul: Z. Melovidov, G. Fratis Sr., and J. Merculief)

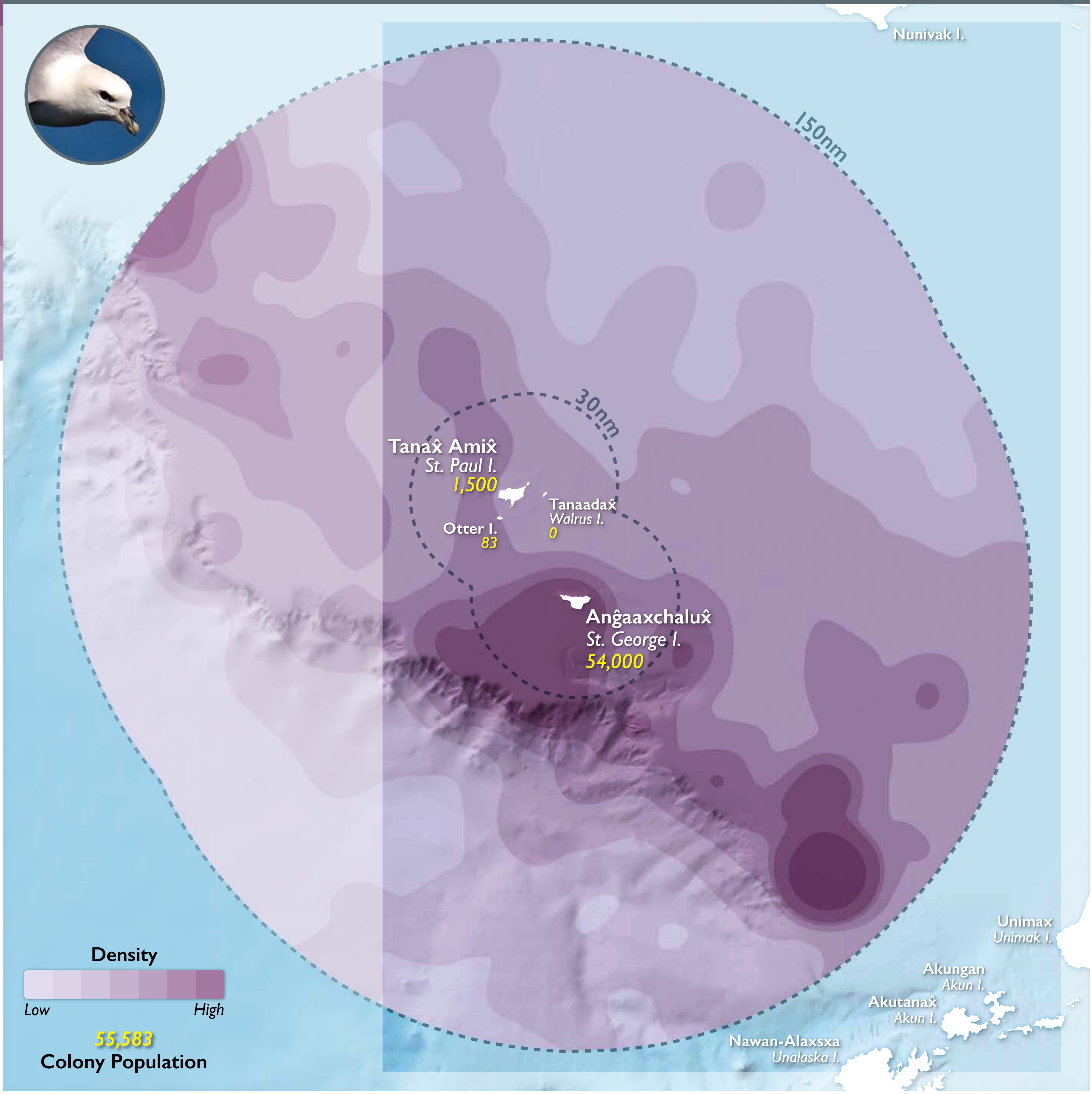


Northern Fulmars, like Black-legged Kittiwakes, are broadly distributed across the Arctic and serve as an important environmental sentinel of marine ecosystem health.

L. Minns / Audubon Photography Awards

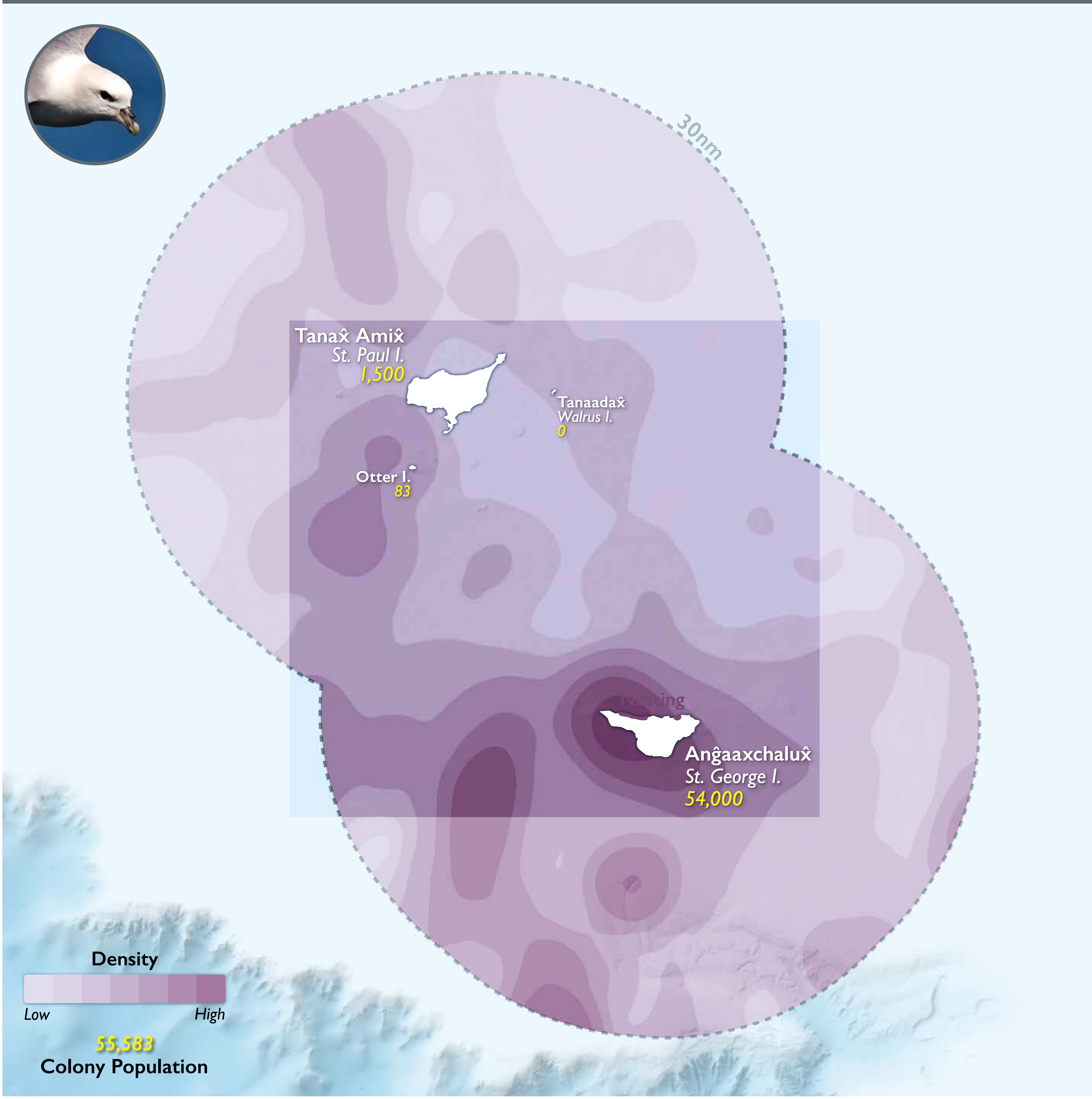
150NM

Northern Fulmar



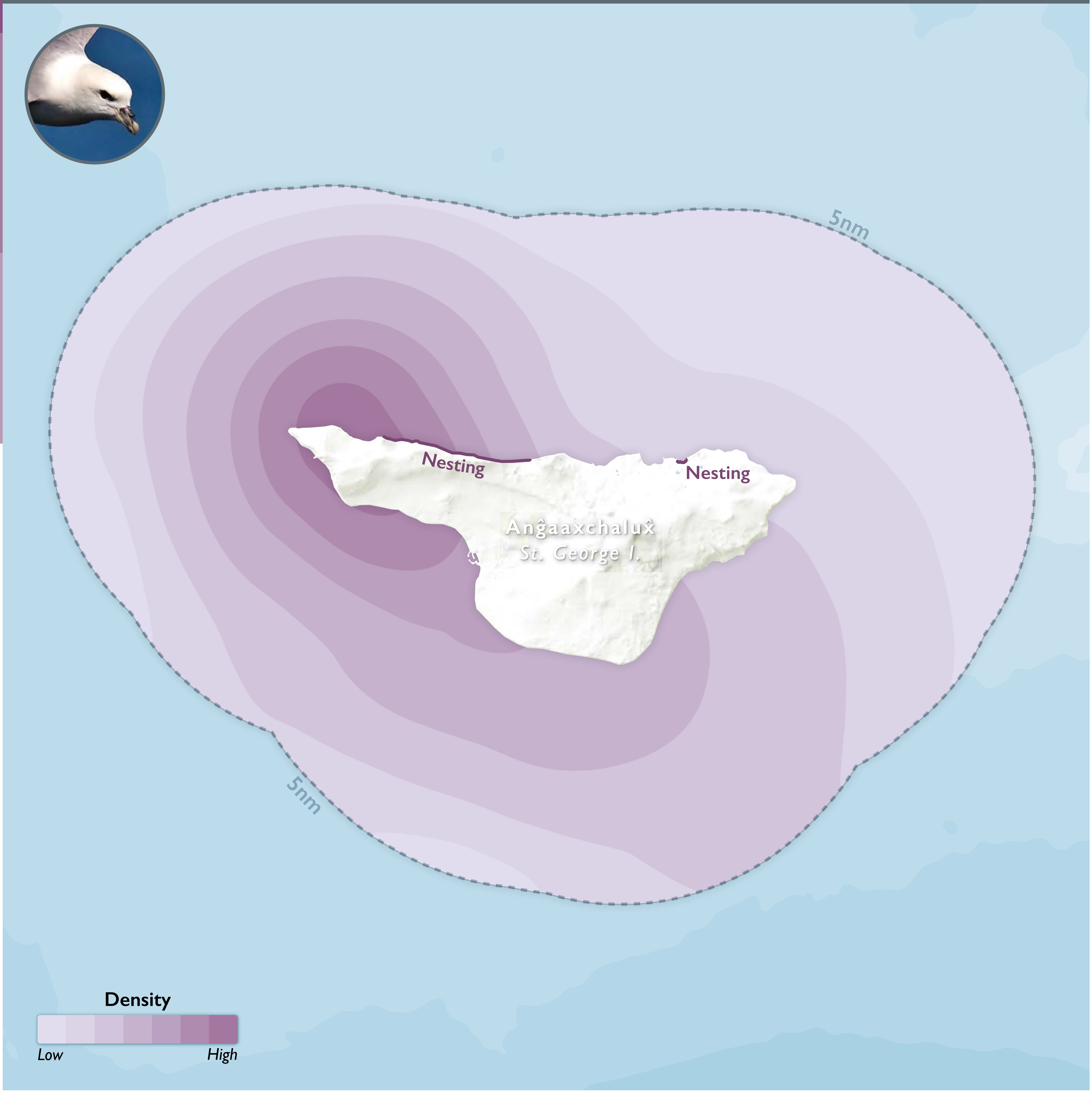
30NM

Northern Fulmar



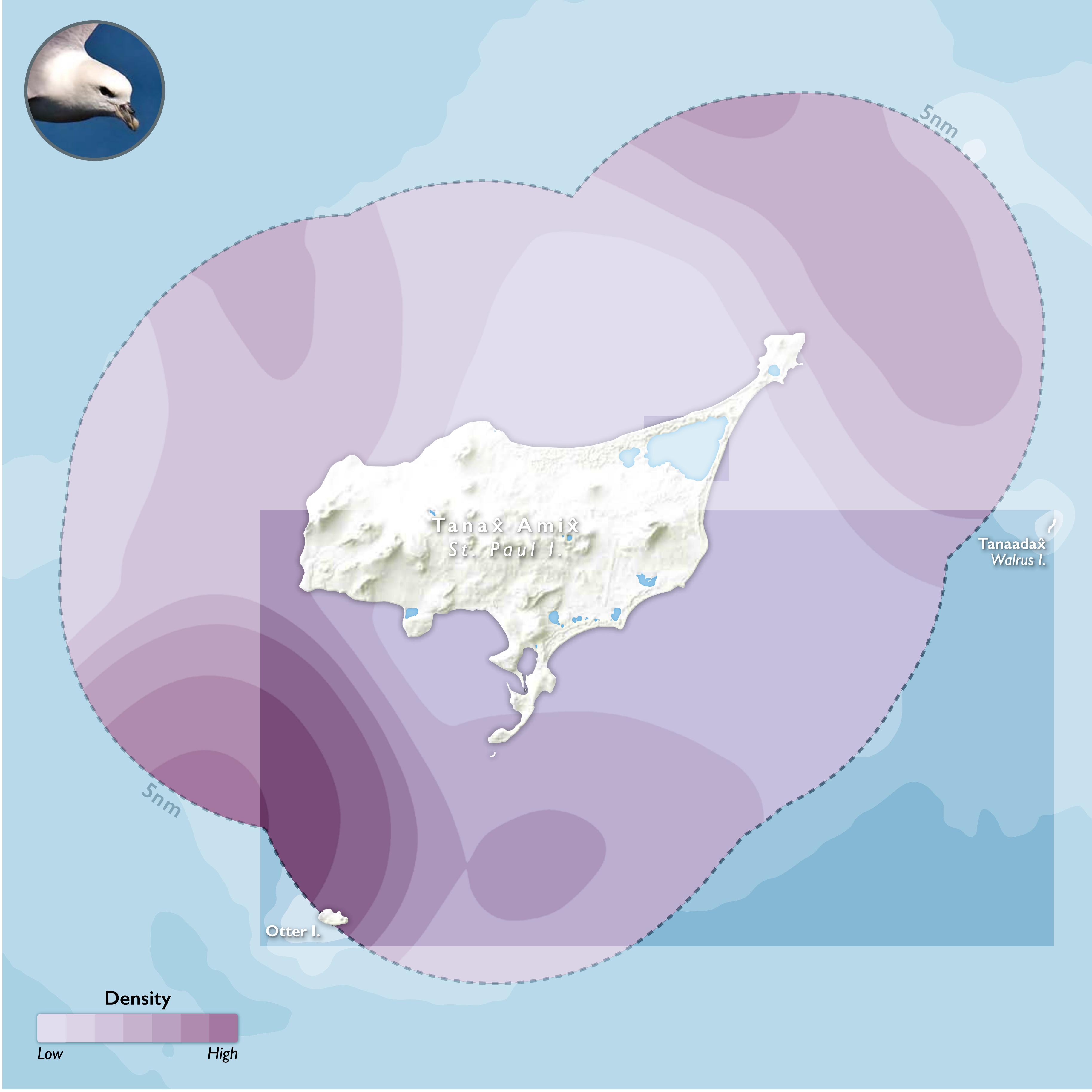
ST. GEORGE 5NM

Northern Fulmar



ST. PAUL 5NM

Northern Fulmar



Glaucous-winged Gull

Slukax̂ (plural *Slukan*) is a general term used to describe any species of gull. The Glaucous-winged Gull (*Larus glaucescens*) is a common, large gull that ranges from northwestern Mexico to Alaska. They are closely related to the Glaucous Gull (*L. hyperboreus*), and Herring Gull (*L. argentatus*), and these species frequently hybridize. Glaucous-winged gulls can be identified by their yellow beak which has a red subterminal spot near the end of the bill; chicks peck this spot in order to stimulate regurgitative feeding from their parents. In late winter and early spring, Glaucous-winged Gulls appear at their colony sites from Alaska to Washington, often before the snow melts. These gulls prefer to nest on grassy hillsides, making a scrape in the ground filled with vegetation such as grasses, moss, weeds, and seaweed. Glaucous-winged Gulls hatch one to four chicks that fledge at 6 weeks as dark brownish gray juveniles (Hayward and Verbeek 2008). Newly fledged juveniles remain with their parents close to nesting territories for several weeks after learning to fly, gradually moving to the sea in September and October (Patten 1974).

Glaucous-winged Gulls are scavengers, feeding near or at the surface of nearshore marine waters, stealing food from other seabird species, and consuming the eggs and chicks of other seabird species.

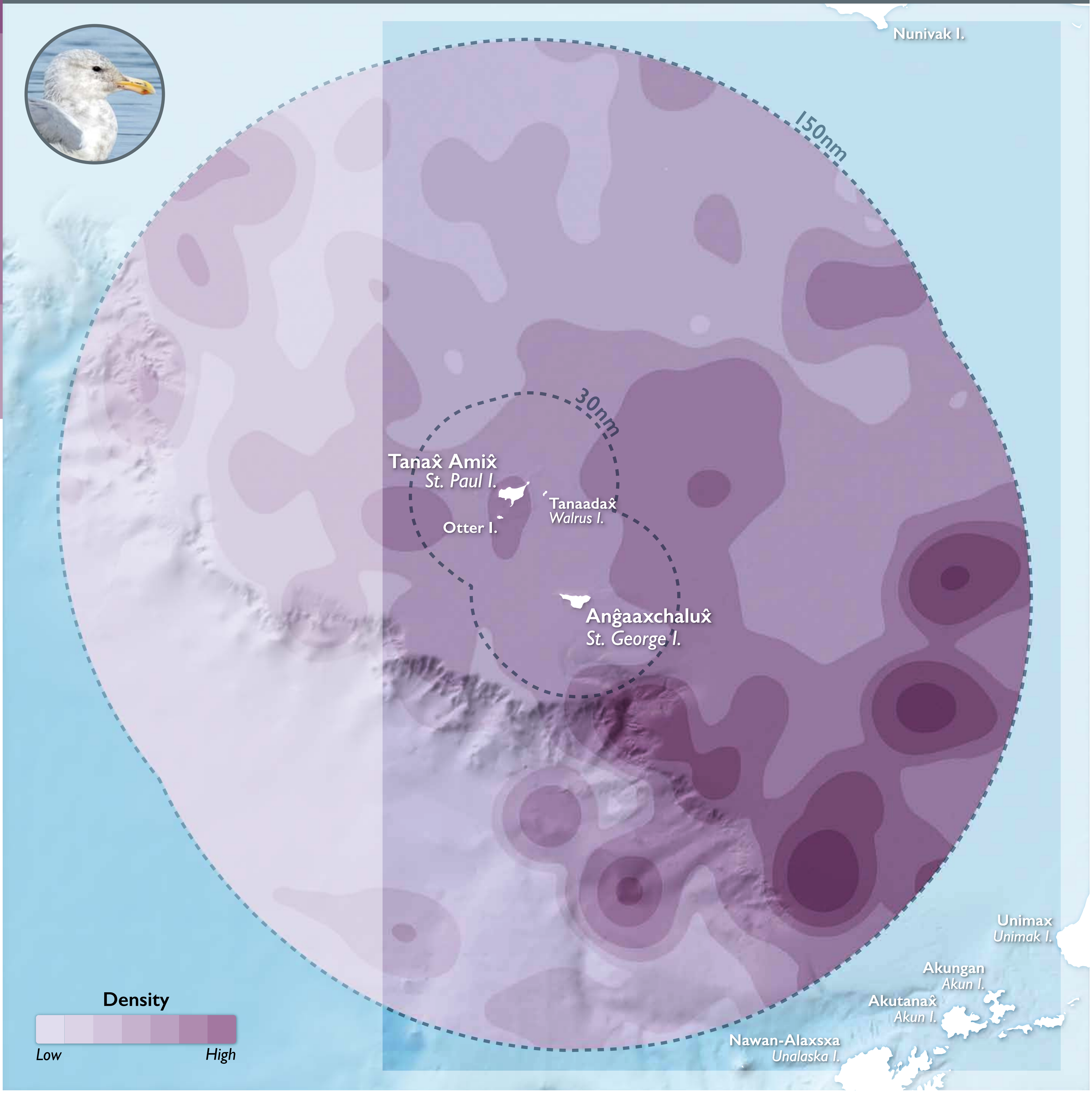
The Pribilof Islands are also wintering sites for the Glaucous-winged Gull, the most abundant *Larus* in the Northeastern Pacific and one of the few Larids that perform large migratory movements. Numbers of seagulls increase at the Pribilof Islands during the winter months, drawn in during peaks of commercial fishing activity.

A large flock of mixed gulls, including Glaucous-winged Gulls, is a common sight in the Salt Lagoon on St. Paul Island.

C. Millbern / UAF CFOS

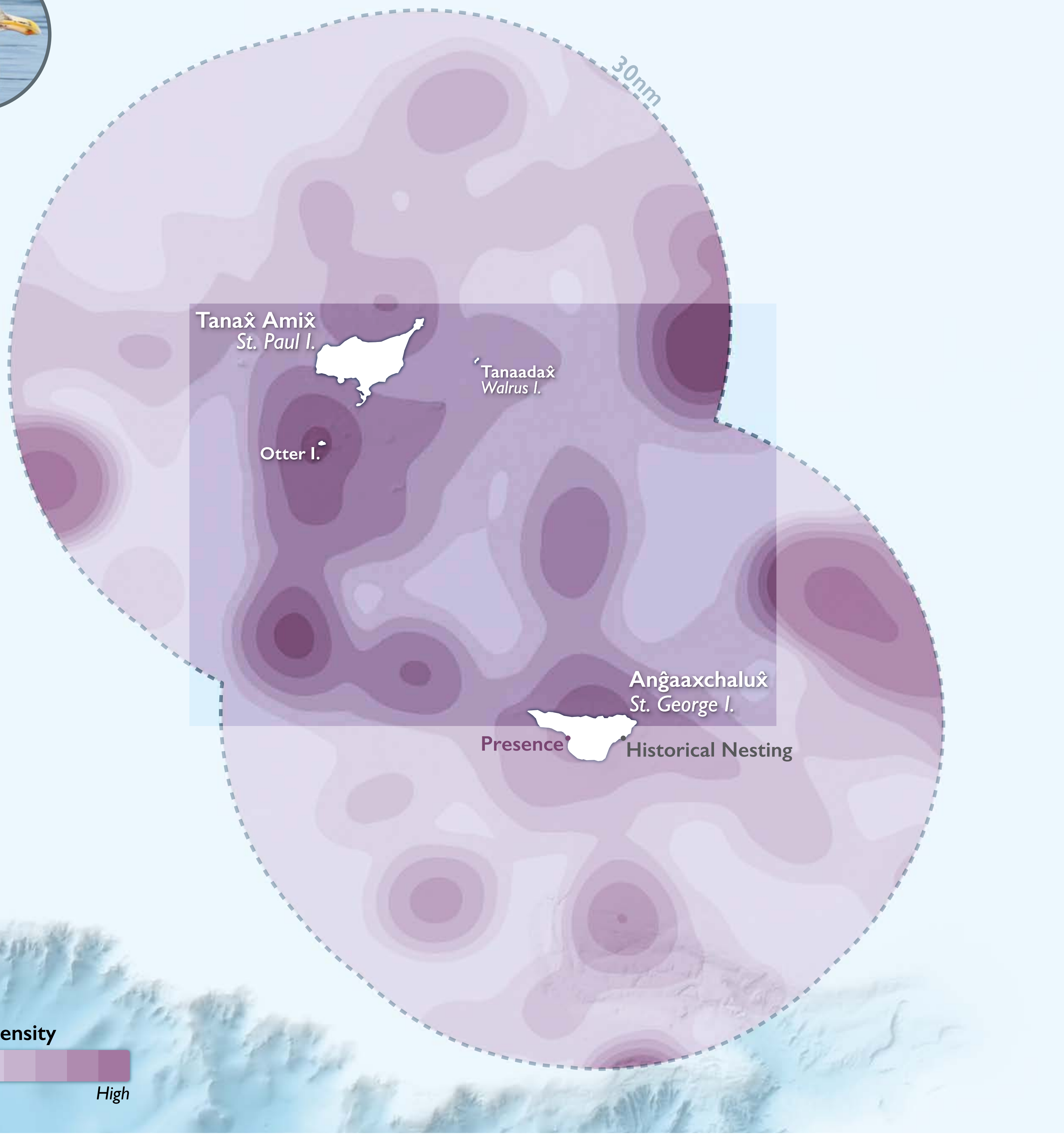
150NM

Glaucous-winged Gull



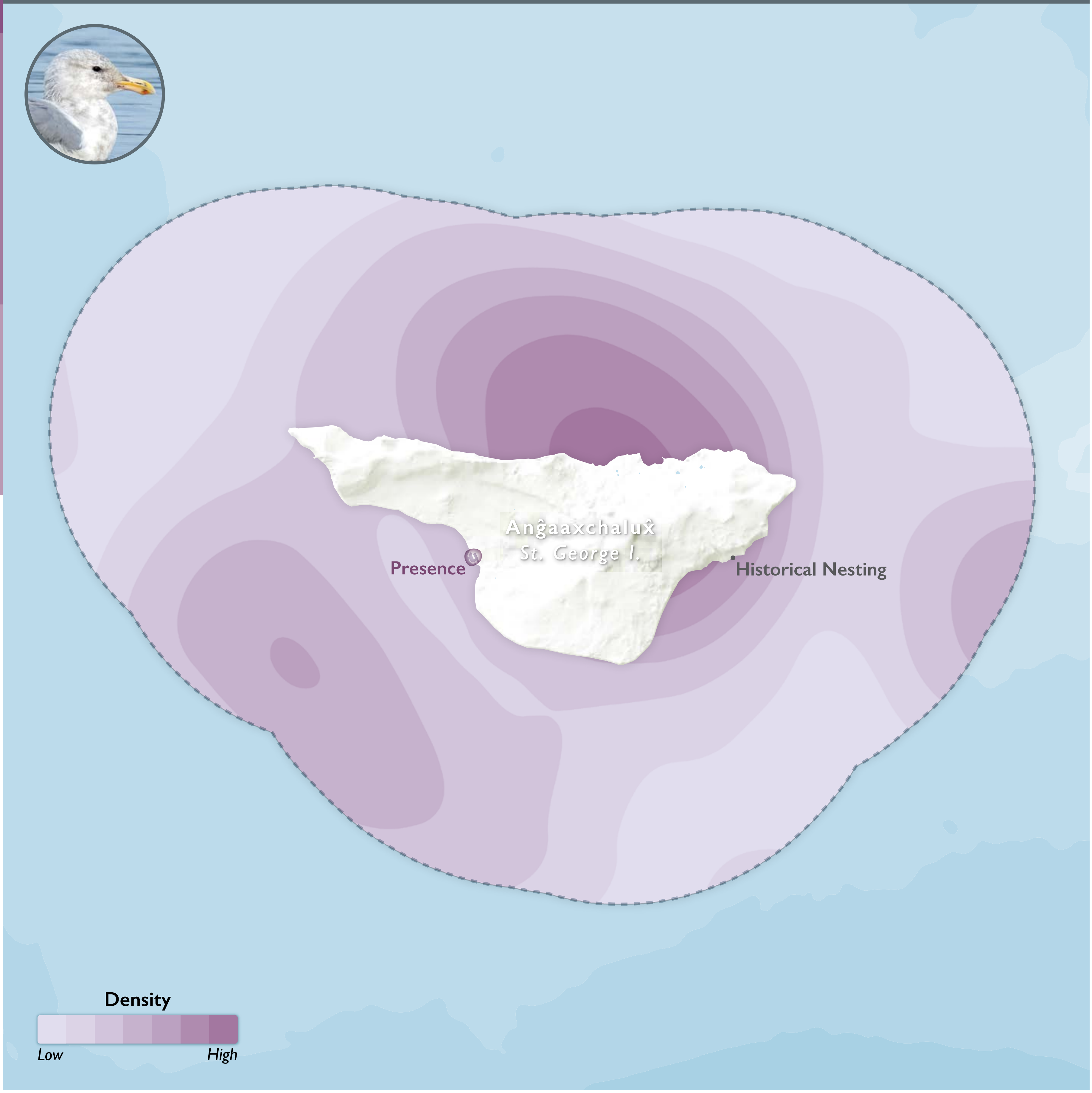
30NM

Glaucous-winged Gull



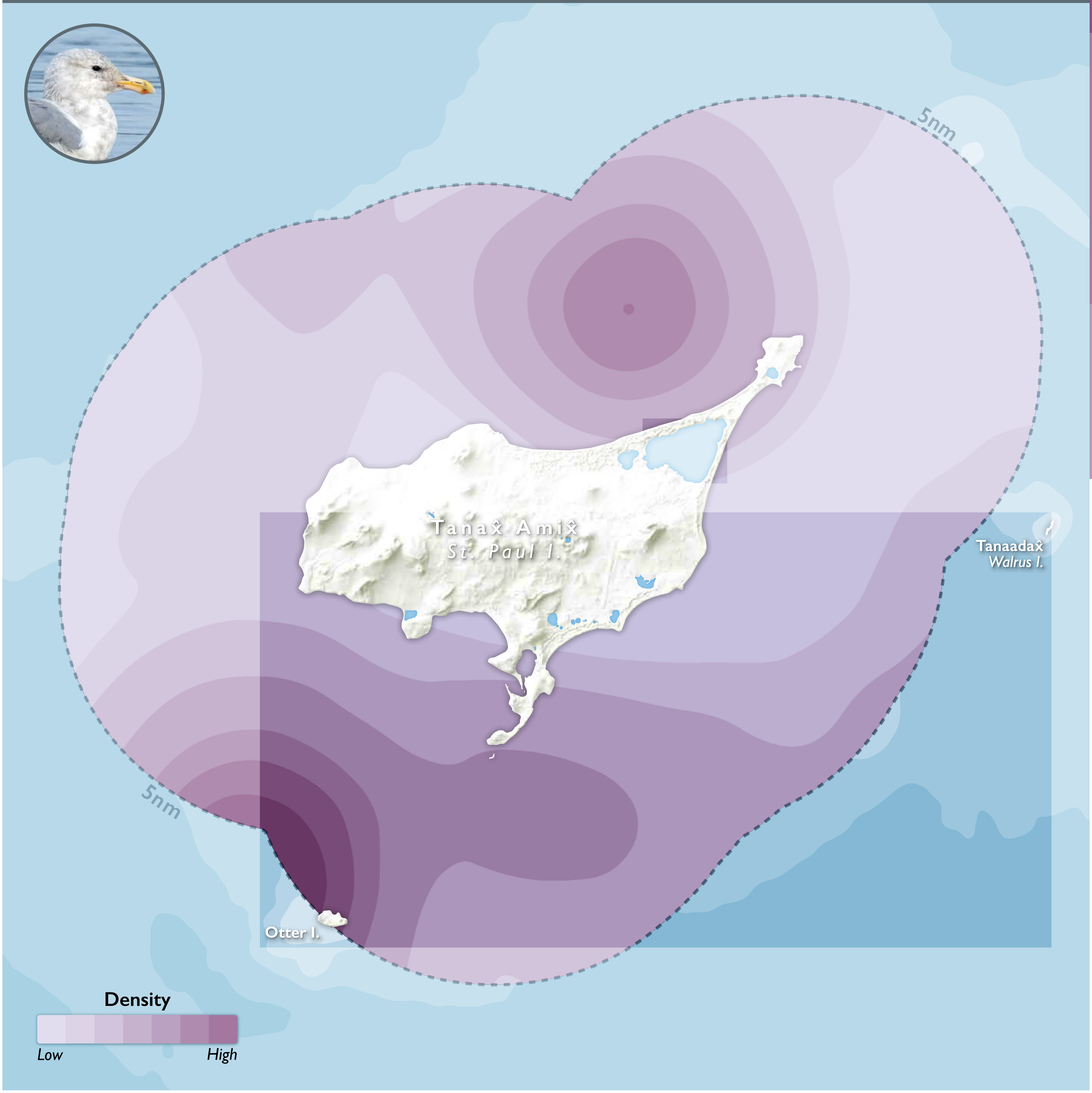
ST. GEORGE 5NM

Glaucous-winged Gull



ST. PAUL 5NM

Glaucous-winged Gull



Sea Ducks

Eiders

The four species of eider (Spectacled Eider, Common Eider [*Kasimax̂*], King Eider [*Saakux̂*], and Steller's Eider) are especially well-adapted to the Arctic climate, spending their entire lives within a few hundred miles of the sea-ice edge (Frimer 1994; Oppel et al. 2011). As such, they spend the majority of their lives at sea, returning to shore only to breed (Johnsgard 1964; Lamothe 1973; Oppel et al. 2009). These hardy Arctic and subarctic birds are among the northernmost nesters on the planet. The four eider species make up two distinct genera within the sea duck subfamily Meringae: *Somateria* (Common Eider [*S. mollissima*; *Kasimax̂*], King Eider [*S. spectabilis; Saakux̂*], and Spectacled Eider [*S. fischeri*]); and Polysticta (Steller's Eider; [*P. stelleri*]). Eiders are among the deepest diving of the more than 20 extant (living) sea duck species, often reaching depths of more than 100 feet (30 m) while foraging for mollusks and crustaceans from the ocean floor. They are covered in especially dense down, which contributes to their ability to withstand the brutal temperatures of the Arctic and subarctic. Male eiders have ornate plumage on their heads during breeding season, which they display to females with head-turning behavior, enticing them to copulate. Their webbed feet allow them to swim and dive extremely well, while the claws they have on each toe enable them to grip the icy substrate often present when they arrive at their breeding grounds (Bent 1925). While diving, eiders use their feet and wings to propel themselves forward. Differences mainly in size allow the four eider species to utilize similar habitats without directly competing for resources (Fox and Mitchell 1997; Merkel et al. 2007a; Merkel et al. 2007b). Because they feed on the ocean floor, they are generally found within 9 miles (15 km) of the shore, or where the continental shelf is not too deep to be accessible or productive (Oppel et al. 2009; Oppel and Powell 2010).

Eiders spend the vast majority of their time at sea. Males spend 11 months a year off-shore, coming ashore only to breed. Females are on land for approximately three months for breeding, but spend the rest of the year in open water. When eiders migrate north during the spring, they form flocks of 10,000–15,000, and up to 100,000 to move from staging and wintering areas to their breeding grounds. Often arriving while the ground is still frozen, they likely choose their nest sites based on which areas thaw and dry first.

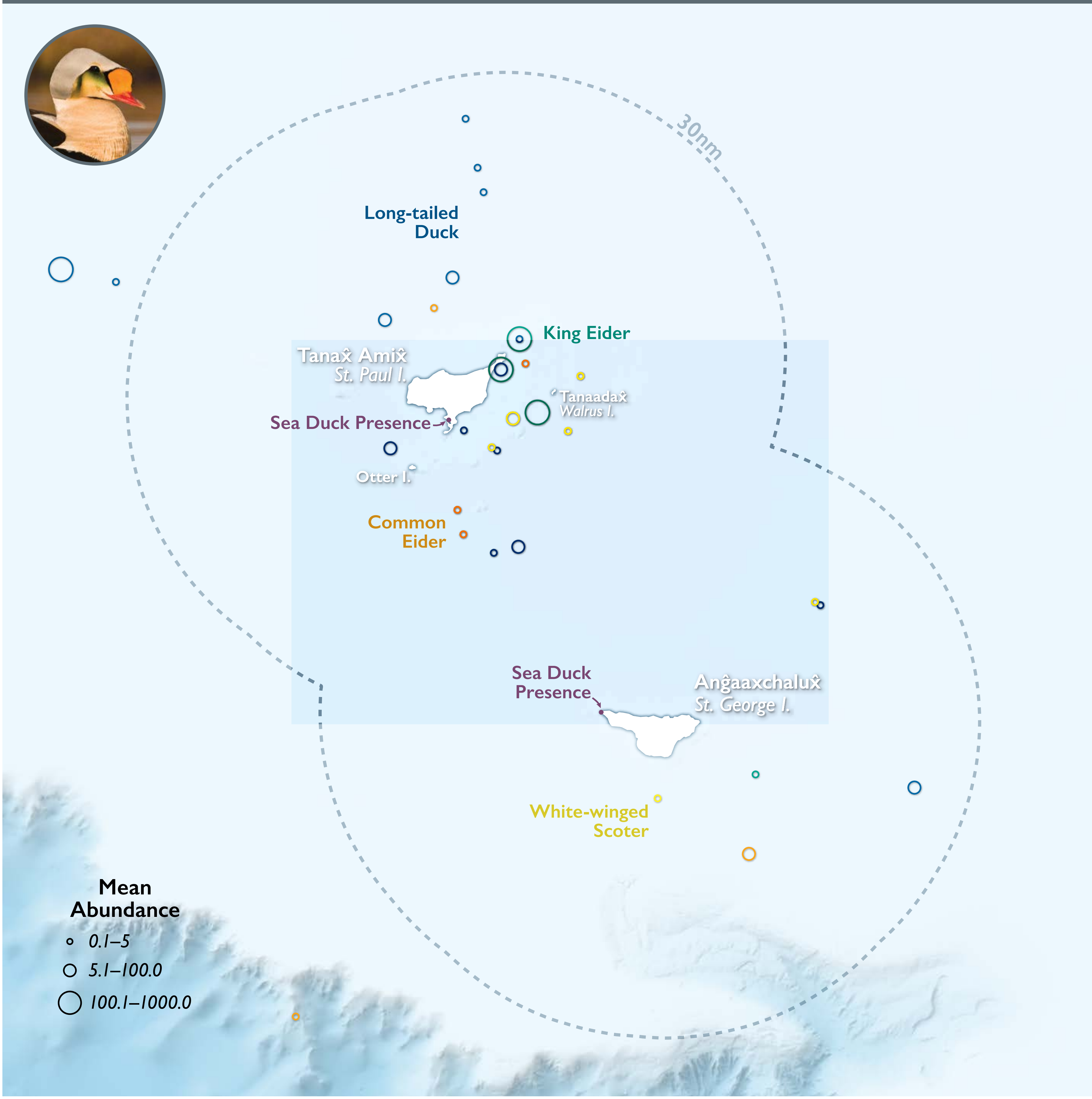
As sea-ice marches south during the fall and winter, many eiders will follow the ice edge as it continues south, feeding at the productive ice margin before departing in relatively small groups for molting areas further south (Powell and Suydam 2012). After molting, many eiders will over-winter in or near their molting areas, or until the advancing sea-ice edge forces them south (Oppel et al. 2008); others will actively migrate to wintering areas. Most Pacific-breeding eiders winter in the Bering Sea, including on the Pribilof Islands, seeking out the sea-ice margins of polynyas or the advancing ice edge. Spectacled Eider, Common Eider (*Kasimax̂*), and King Eider (*Saakux̂*) are most commonly observed overwintering on the Pribilof Islands and are utilized as subsistence resources (see Subsistence Birds section; page 62). Eiders are often not sedentary during winter; some *Saakun* will travel up to 1,000 miles (1,600 km) among three or more wintering sites, while other eider species will remain at a single site throughout the winter months. Sea-ice concentration and food availability are the likely causes for winter movements (Oppel et al. 2008; Oppel et al. 2009).

Long-tailed Ducks

Aalngaaĝix̂ or Long-tailed Ducks (*Clangula hyemalis*) are small sea ducks with elongated tail feathers that breed in the northern portions of the coastal Arctic. They molt three times, with substantial plumage changes throughout the year. These highly vocal sea ducks breed on the North Slope of Alaska, with substantial populations also breeding in the Yukon-Kuskokwim (Y-K) Delta and coastal areas of Amundsen Gulf, Canada. Before migrating toward their summer breeding habitat, *Aalngaaĝin* traditionally gathered in polynyas in the northern Bering Sea and leads to forage, though recent reductions in sea-ice concentration have rendered these areas ice-free earlier than usual. After staging, they make the journey north in small groups, arriving in April or May, well before the sea-ice margin has receded or their nesting habitat has thawed. After breeding, males precede females to molting areas where they molt their flight feathers. After molting, they prepare for fall migration, taking advantage of numerous staging areas to replenish energy stores used during migration by consuming small crustaceans on the sea floor. *Aalngaaĝin* that breed in the project area commonly arrive in November and December to spend the coldest months in the Bering Sea, with substantial wintering populations in the Gulf of Anadyr, near St. Lawrence Island, off the coast of the Y-K Delta, and among the Aleutian Islands.

30NM

Sea Ducks



Human Uses

MAPS

COMMERCIAL FISHING

C. Arnold

Commercial Fishing

Alaskan marine waters have always been a sustained source of seafood for people of the Bering Sea. Indigenous harvests of fish, shellfish, and marine mammal proteins have been important and long-standing traditions that continue to this day. Contemporary commercial fishing has a shorter history, but a nonetheless vast impact. In the early-to-mid 1900s, commercial fishing vessels from Japan, the Soviet Union, South Korea, Poland, and Taiwan fished alongside US vessels to exploit the Bering Sea's natural marine resources (National Oceanic and Atmospheric Administration 2004). Targeted fish species for both foreign and domestic fleets included walleye pollock (*Gadus chalcogrammus*), Pacific cod (*G. macrocephalus*), Pacific salmon (*Oncorhynchus* spp.), and Pacific halibut (*Hippoglossus stenolepis*; Atkinson 1988; National Marine Fisheries Service 2004). The implementation of the Fishery Conservation and Management Act—later amended as the Magnuson-Stevens Fishery Conservation and Management Act (MSA)—substantially increased the marine area managed by the US. Up until 1976, federal jurisdiction covered 12 miles (19 km) offshore, but the MSA extended jurisdiction to 200 nautical miles (370 km), which encompasses the exclusive economic zone (EEZ; National Marine Fisheries Service 2007). The State of Alaska manages fishery resources in state waters within 3 nautical miles (5.5 km) from shore. Additionally, some species that are transboundary are managed through agreements with US neighboring countries. The US has management agreements with Russia for walleye pollock in the 'Donut Hole', the area between the US and Russia EEZ (Bailey 2011) and for Pacific halibut with Canada (Bell 1969). The US also joins Canada, Japan, Russia, and the Republic of Korea in a Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean, which works to promote conservation of Pacific salmon populations (North Pacific Anadromous Fish Commission 2003).

Today, over half of U.S. seafood production is caught in the eastern Bering Sea (EBS) by US vessels and fishing companies (North Pacific Fishery Management Council 2016). Over 1,060 commercial fishing vessels are federally registered in the EBS to catch and process that seafood either as catcher vessels; catcher/processors; or motherships, with trawl, pot, longline, jig, gillnet, or troll gear. The presence and behavior from those fishing vessels have direct impacts on the Pribilof Islands and broader EBS marine ecosystems in several ways: removal of large amounts of fish and crabs from marine food webs affect target and bycatch species populations as well as having trophic effects on predators and prey; ship traffic and fishing gear interacts with seabird and marine mammals at or near the sea surface; disrupting benthic (seafloor) communities, with trawl gear having the most detrimental effects (Chuenpagdee et al. 2003); and benthic habitat destruction via fishing gear interactions subsequently impacts fish and crab species relying on corals, sponges, and other habitat-forming invertebrates for essential protective structures. Trawling reduces habitat complexity through the removal of structural benthic invertebrates, smoothing the sediment, and, when an area is fished repeatedly, trawling hinders recovery of these seafloor communities (Bradshaw et al. 2002).

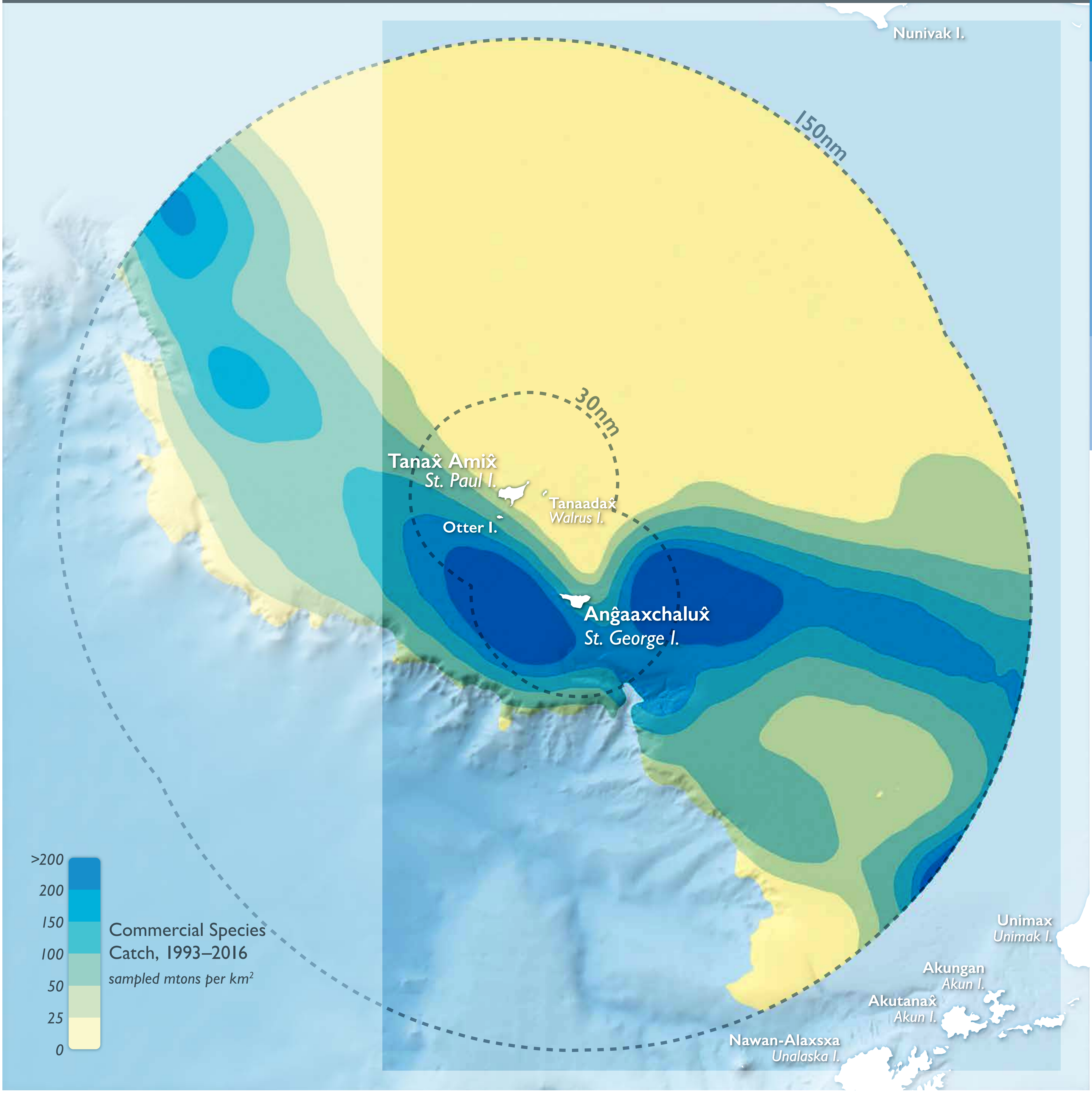
High removals of fish and crab biomass can affect the marine ecosystem by disrupting the food chain or through localized depletion of a particular population or stock. Areas where high fisheries removals overlap areas with predators of the same commercial species could be vulnerable to localized depletion and may require different spatial fishing allocations (Plagányi and Butterworth 2012). For example, the middle domain of the southern Bering Sea experiences above average commercial fishery removals while also supporting several piscivorous fish, marine mammals, and seabirds. In addition, this area is likely to experience changes due to ocean warming, with commercially targeted fishes and crabs moving northward (Orensanz et al. 2004; Zheng and Kruse 2006). The combination of fishing, natural mortality, and climate change-induced community composition changes makes the area vulnerable to localized depletion.

Because removals of biomass on an industrial scale in the EBS by federal groundfish fisheries impacts all levels of the ecosystem, as listed above, these activities are limited to some extent. Prior to establishing the EEZ, the more than 300 vessels in the foreign fleets harvested up to 2.6 million tons (2.4 million metric tons) per year (National Oceanic and Atmospheric Administration 2004). After federalizing Alaska waters, the annual fisheries removals reached over 2.2 million tons (2 million metric tons) by the 1990s, and by regulation the EBS federal groundfish fisheries removals are now capped at that level (National Marine Fisheries Service 2004). As a result, the populations of those targeted and incidentally caught species are lower than they would have been due to natural mortality alone.

Many areas with high fisheries removals reflect areas with high fish and crab abundance, and thus do not necessarily imply overfishing. However, one prudent measure to safeguarding against overfishing is utilizing an ecosystem-based fisheries management approach. This approach evaluates vulnerability to overfishing in a manner that considers the species-specific impacts of fisheries removals. For instance, a target species may be plentiful in an area with high fishing activity, but bycatch species' stocks may be vulnerable to fishing mortality, warranting consideration on limiting targeted commercial fishing activity through gear-type regulations and/or seasonal restrictions to mitigate impacts and ensure sustainability of non-targeted species. Close monitoring of the localized populations would aid in mitigating any species-specific stock declines by ensuring a balance between commercial fishing removals and other needs, such as prey for sustaining seabirds and marine mammals in the region (Pikitch et al. 2004).

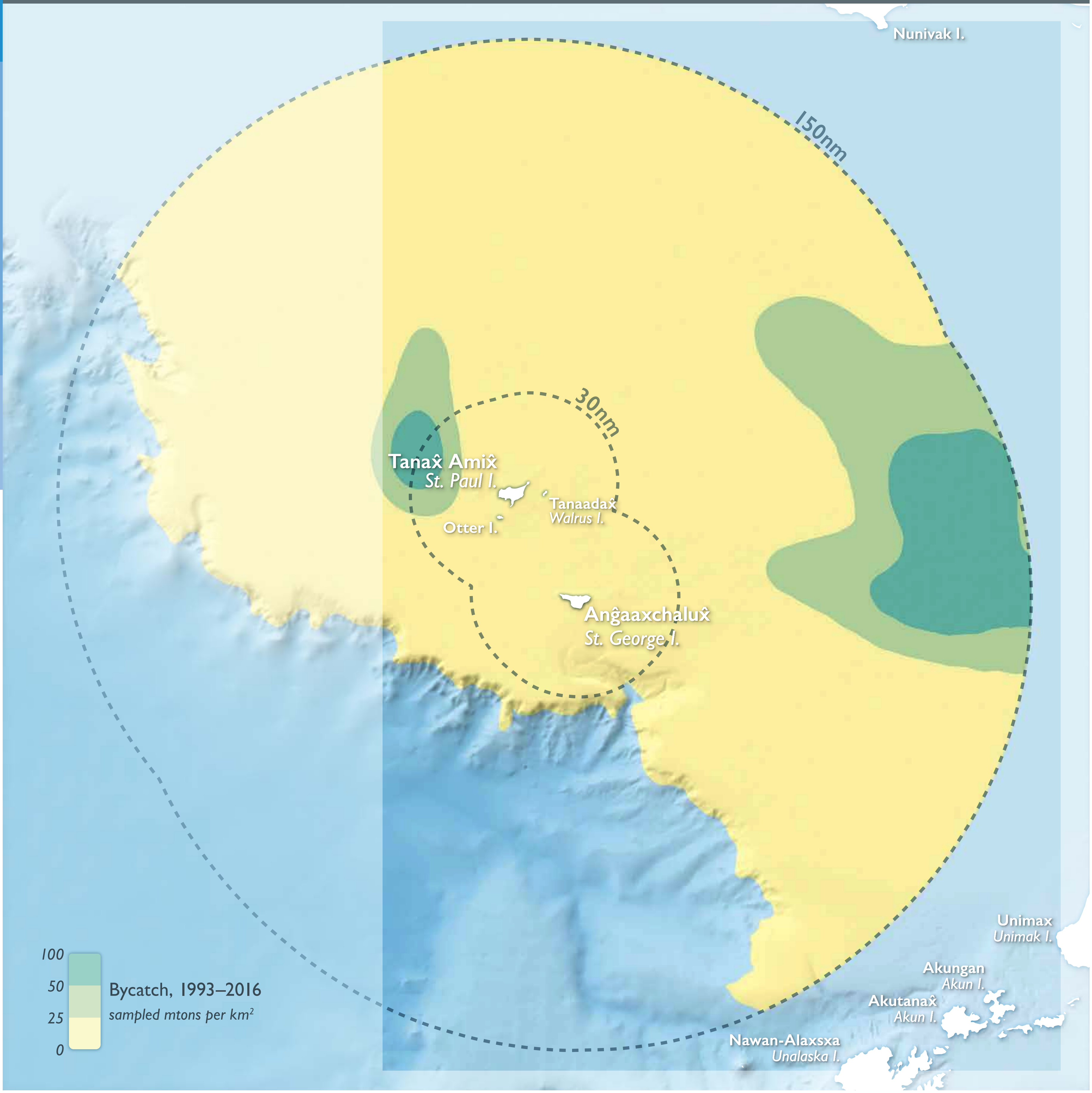
150NM

Commercial Fish Species



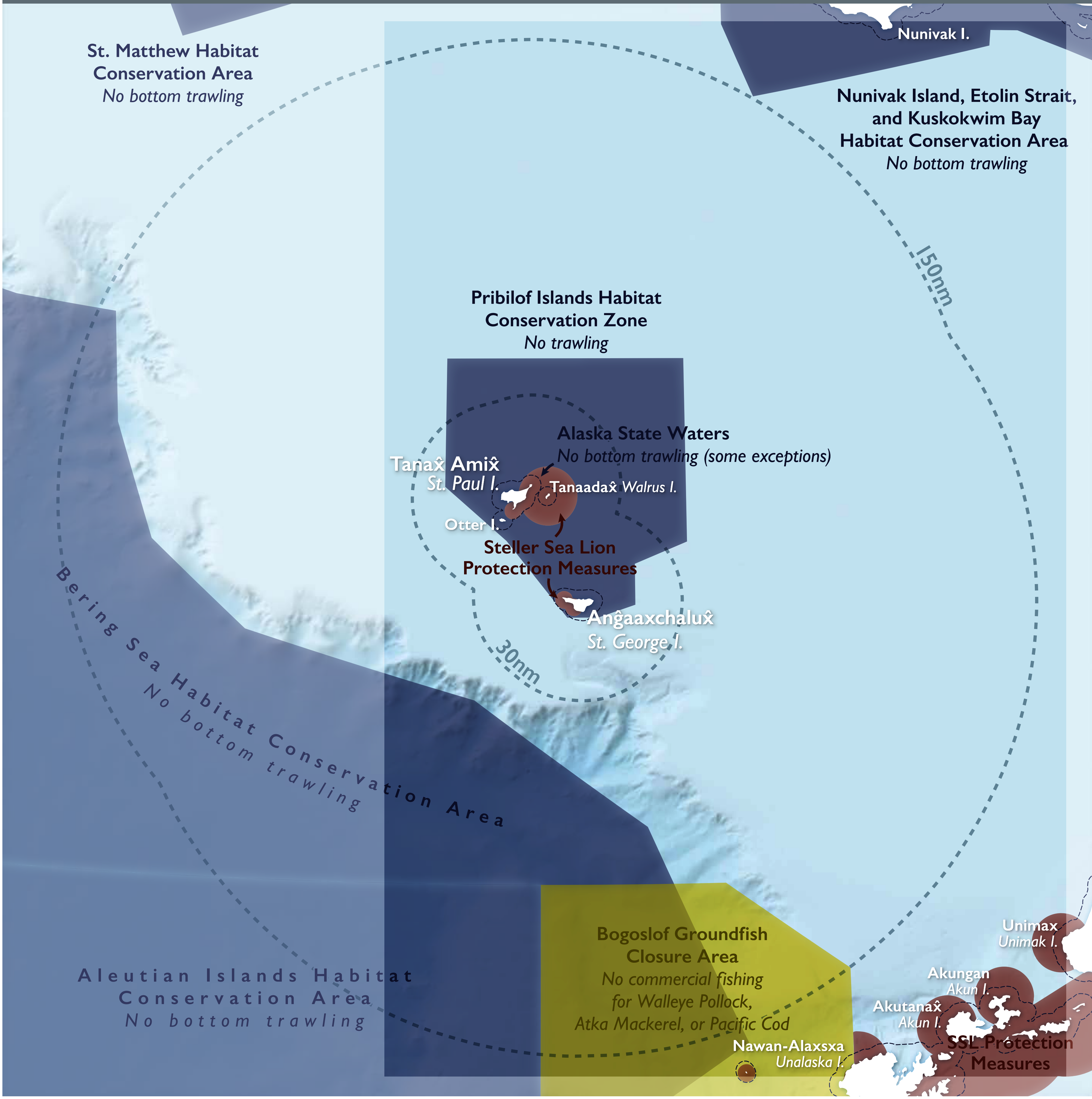
150NM

Bycatch



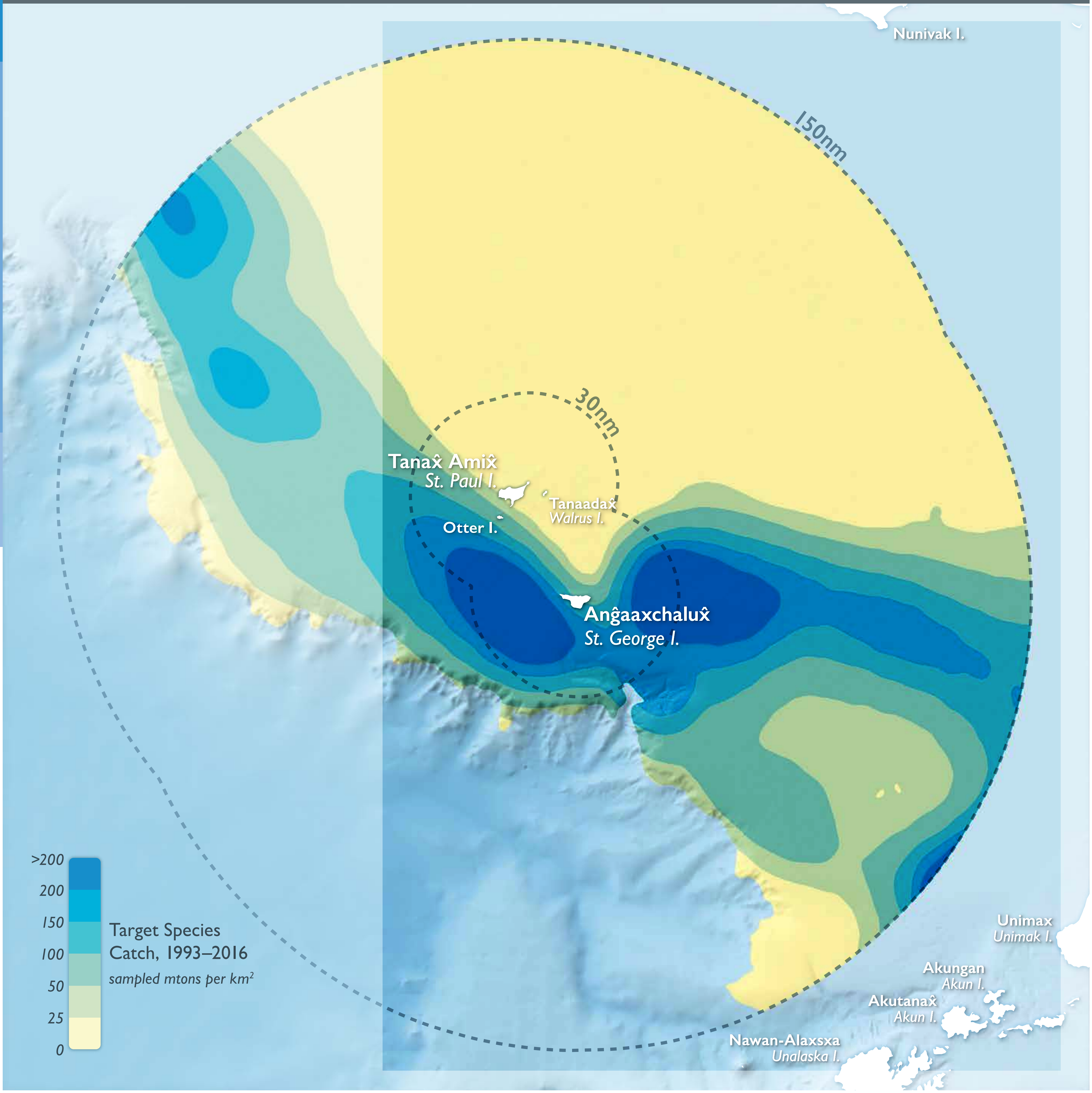
150NM

Protection Closure



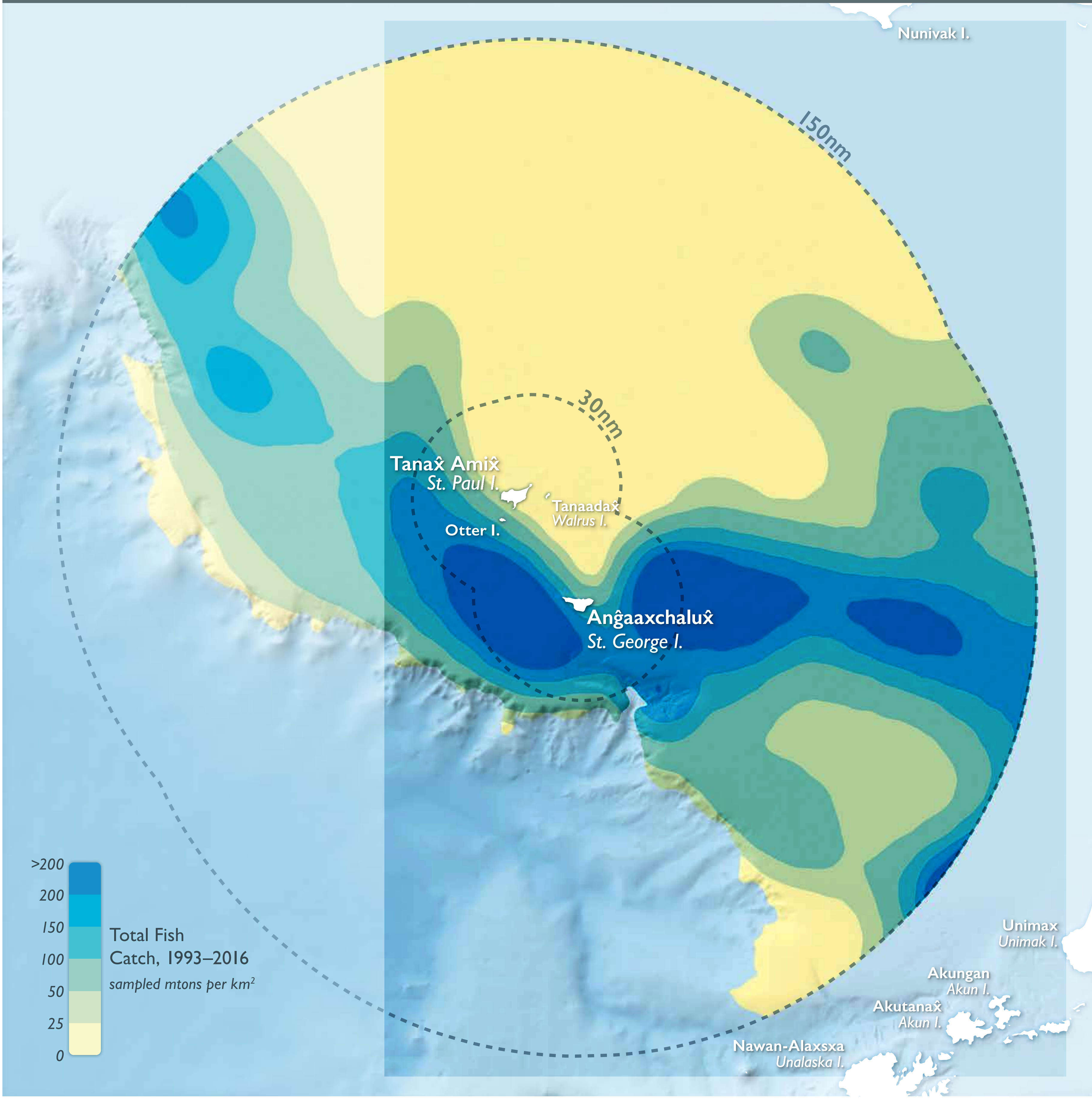
150NM

Target Species



150NM

Total Catch



Vessel Traffic

By Ben Sullender and Max Goldman

Introduction

Vessel-based commerce and transportation is heavily utilized in the southern Bering Sea. Tankers, cargo vessels, and barges led by tugboats transport minerals, fuel, goods, and various freight. The Pribilof Islands lie within a heavily trafficked corridor of Bering Sea waters. Vessels of all types traverse this region to transport goods and harvest fish, though few vessels are delivering goods to the islands themselves. Climate change continues to diminish Arctic sea ice, extending the open water period more each year. With sea ice presence excluding vessel transits for fewer months each year, traffic around the Pribilof Islands will likely increase dramatically, as all Arctic vessel traffic increases. More vessel transits means higher vulnerability to the potential and inherent ecological impacts that accompany each vessel in the Bering Sea.

Impacts

Given their central role in Arctic marine communities, it is important to understand the ecological risks that vessels pose to the marine environment. Broadly, these risks can be classified into five main categories: oil spills, ship strikes, noise pollution, discharges and emissions, and invasive species. These risks may be chance events—such as an oil spill—that may not necessarily occur, or may be an inherent part of vessel travel in a given region, such as impacts arising from noise pollution. The Ocean Conservancy's recent report *Navigating the North: An Assessment of the Environmental Risks of Arctic Vessel Traffic* (Ocean Conservancy 2017) provides more detailed descriptions of individual environmental threats and includes an excellent overview of relevant regulatory framework.

Oil Spills

An oil spill in an area as remote as the Pribilof Islands has the potential to be ecologically catastrophic, and represents the single greatest threat from vessels to the marine environment (Arctic Council 2009). Vessels typically carry at least some amount of oil, whether for use as fuel or for carriage as cargo, and many vessels still use heavy fuel oil (HFO), which can be 50 times as toxic to marine organisms as regular fuel oil (Bornstein et al. 2014). The acute and chronic effects of oil exposure are relatively well described, and oil is known to be toxic to a wide range of organisms (Burger and Fry 1993; National Research Council 2014). In addition to individual mortality, exposure to oil can lead to changes in reproduction, survival, and behavior (Rocque 2006; Nahrgang et al. 2016), with cascading implications across population demography and across an entire ecosystem (Peterson et al. 2003). The near-surface life histories of species such as seals, sea lions, seabirds, and shorebirds increase their chances of encountering contaminated areas. Oil alters the thermal balance of these organisms by reducing the water-repelling properties of fur (Davis et al. 1988), and, for birds, reactionary grooming spreads the oil deeper, accelerating and intensifying its effects (Davis et al. 1988; Jenssen 1994).

Although there have been numerous historical shipwrecks across the Bering Sea, there have been few recent incidents, almost exclusively in the southern Bering Sea. The groundings of the F/V *Kuroshima* in 1997 and M/V *Selendang Ayu* in 2004 resulted in the loss of life of crewmembers and released 39,000 gallons and 350,000 gallons of oil, respectively (National Oceanic and Atmospheric Administration 2002; Ropeik 2014). The physical oceanography of the Pribilof Islands region has the potential to exacerbate oil spills. Regularly persistent winds, and strong currents may impede natural weathering processes of oil, impair clean-up efforts, and disperse oil over a broader area (National Oceanic and Atmospheric Administration 2002). Furthermore, the predominant currents that contribute to biological productivity in the region would also concentrate spilled oil in these same ecologically important places (National Oceanic and Atmospheric Administration 2017).

Threat 2: Ship Strikes

Ship strikes, when a vessel collides with a marine organism, have the potential to become more of an acute issue as vessel traffic increases, particularly for large cetaceans (Vanderlaan et al. 2009). The marine areas adjacent to the Pribilof Islands serve as important cetacean habitat as they are positioned within the southern extent of bowhead whale (*Balaena mysticetus*) range and along the foraging and migration paths of humpback whales (*Megaptera novaeangliae*), gray whales (*Eschrichtius robustus*), and many other less common large cetacean species. When paired with high shipping vessel transits through the region, fatal ship strikes become more likely. Already, fatal injuries resulting from ship strikes are a surprisingly prevalent source of worldwide whale mortality: ship strikes were the lead cause of 14% of observed whale mortalities in the Atlantic (Laist et al. 2001), 15% of whale mortalities in Washington state (Douglas et al. 2008), 35% of mortalities in the North Atlantic right whale population (Knowlton and Kraus 2001), and 23% of all observed whale mortalities in the North American Atlantic (Van Der Hoop et al. 2013). Within the Alaskan Arctic, rates of non-fatal ship strikes appear to have increased from 0.8% of bowhead whales harvested from 1976-1992 (George et al. 1994) to 2% of whales harvested from 1990-2012 (George et al. 2017), although there is some overlap in sampling records. These data are also strongest in the Beaufort Sea, where bowhead survey efforts are most robust.

Evidence also suggests that whales can become entangled, sometimes fatally, in fishing gear (Moore and Clarke 2002), with 12% of harvested bowhead whales in the Bering, Chukchi, and Beaufort Seas showing scarring from non-fatal entanglement (George et al. 2017) although the commercial crab fishing season and bowhead whale distribution are generally considered to not overlap (Citta et al. 2014).

When cetacean-ship strikes occur, evidence suggests that higher vessel speeds result in higher rates of collision (Gende et al. 2011; Neilson et al. 2012) and more severe injury (Laist et al. 2001; Vanderlaan and Taggart 2007). To reduce the potential for fatal vessel strikes, NOAA's National Marine Fisheries Service recommends that a speed limit of 10 knots be applied seasonally to all vessels over 65 feet transiting areas hosting aggregations of large cetaceans (Silber and Bettridge 2012).

Threat 3: Noise Pollution

While ship strikes and oil spills are stochastic, infrequent events, acoustic disturbance from vessels is a constantly occurring impact. Marine mammals rely on sound for predator avoidance, socialization and communication, prey detection, and navigation (Richardson 1995), and anthropogenic noise reduces the area over which marine mammals can hear and communicate, leading to a functional degradation of habitat (Moore et al. 2012). Noise-related impacts include behavioral (changes in swimming patterns), acoustic (changes in vocalizations), and physiological (stress responses and hearing system damage; Nowacek et al. 2007; Peng et al. 2015; National Marine Fisheries Service 2016).

Threat 4: Discharge/Emissions

Vessels generate a range of waste products, from sewage and solid food waste to oily bilge water and airborne particulate matter including black carbon. Different classes of waste products are subject to differing regulations, which also depend on vessel attributes such as size, but most waste products are either discharged, stored, or treated in some way (Ocean Conservancy 2017). With larger-capacity vessels such as cruise ships, limited on-shore treatment capabilities and the high volume of waste make management a pressing concern in the shipping industry (Arctic Council 2009).

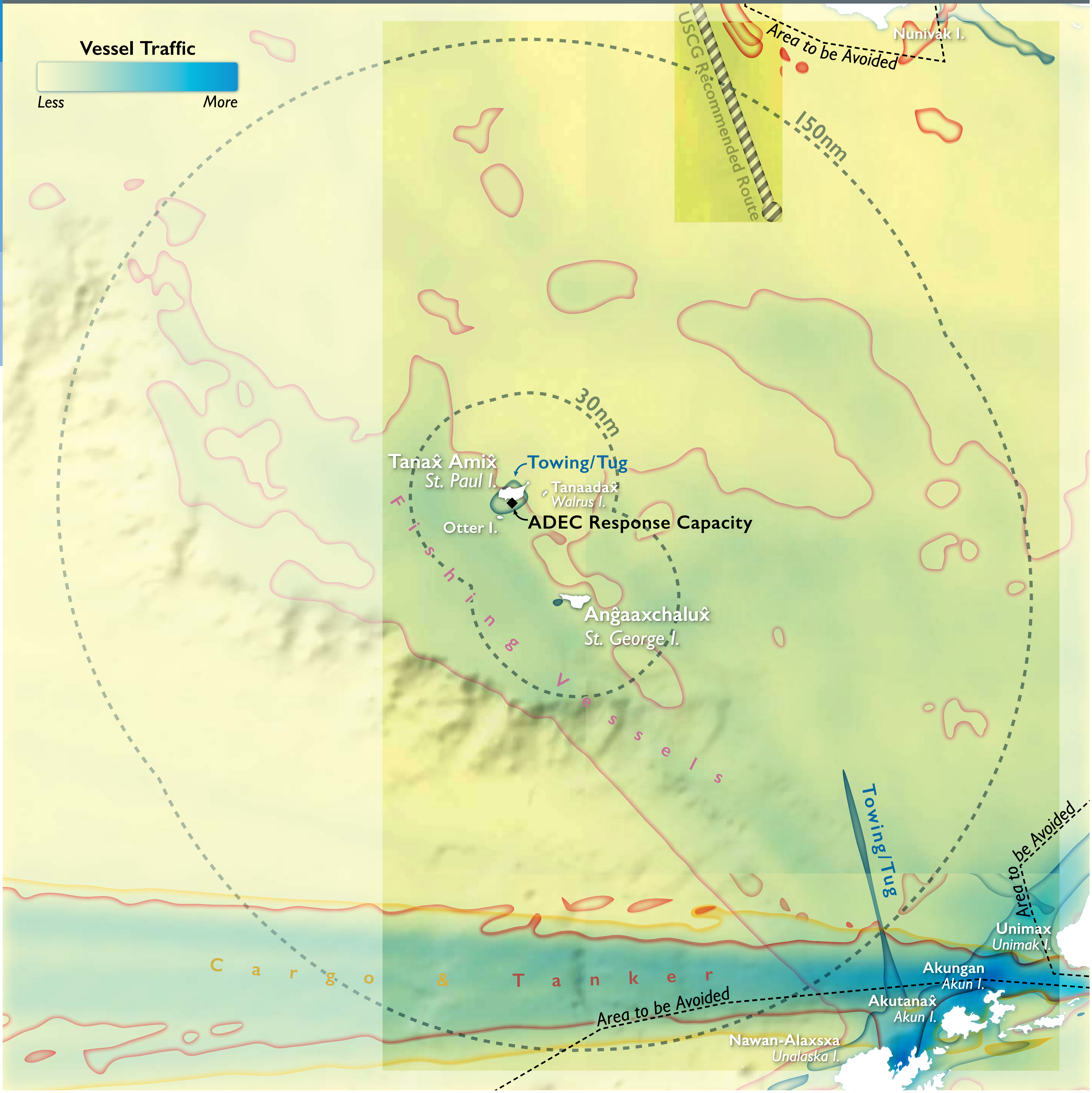
Threat 5: Invasive Species

Vessels can serve as vectors for the introduction of non-native marine species into novel environments through mechanisms such as hull fouling, ballast water discharge, and discarded equipment (Bax et al. 2003). While many non-native organisms that are released into a novel environment will not survive transport or will not flourish in their new environments, some may become established and outcompete, prey upon, or displace native species. Although very few marine invasive species have been documented in the Pribilof Islands marine environment to date, climate change is predicted to make Alaska waters generally more suitable for a wide range of invasive taxa, increasing the likelihood of establishment in the future (de Rivera et al. 2011).

iStock

150NM

Vessel Traffic



iStock

References

Ainley, D. G., D. N. Nettleship, H. R. Carter, and A. E. Storey. 2002. Common Murre (*Uria aalge*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/commur/introduction.

Allen, B. M., and R. P. Angliss. Alaska marine mammal stock assessments, 2013. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-277, 294 p.

Andrews, A. H., E. E. Cordes, M. M. Mahoney, K. Munk, K. H. Coale, G. M. Cailliet, and J. Heifetz. 2002. Age, growth and rediometric age validation of a deep-sea, habitat-forming gorgonian (*Primnoa resedaeformis*) from the Gulf of Alaska. *Hydrobiologia* 471:101-110.

Antonelis, G. A., Jr and M. A. Perez. 1984. Estimated annual food consumption by northern fur seals in the California Current. *CalCOFI Rep* 25:135-145.

Arctic Council. 2009. Arctic Marine Shipping Assessment 2009 Report. Tromsø, Norway.

Armstrong, D. A., J. L. Armstrong, G. Jenson, R. Palacios, and G. Williams. 1987. Distribution, abundance, and biology of blue king and Korean hair crabs around the Pribilof Islands. U.S. Department of Commerce, NOAA.

Atkinson, C. E. 1988. Fisheries Management: An Historical Overview. *Marine Fisheries Review* 50:111-123.

Audubon Alaska. 2016. Alaska Geospatial Bird Database v2. Audubon Alaska, Anchorage, AK.

Audubon Alaska. 2017. Bird Survey Effort GIS File. Audubon Alaska, Anchorage, AK.

Bailey, K. M. 2011. An empty donut hole: The great collapse of a North American fishery. *Ecology and Society* 16:28.

Barbeaux, S., J. Ianelli, and W. Paulson. 2016. Aleutian Islands walleye pollock SAFE, *In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions*. North Pacific Fishery Management Council, Anchorage, AK.

Bax, N., A. Williamson, M. Aguero, E. Gonzalez, and W. Geeves. 2003. Marine invasive alien species: A threat to global biodiversity. Marine Policy 27:313-323.

Bechtol, B., Cleaver, S., Daly, B., Dorn, M., Eckert, G., Foy, R. J., Garber-Yonts, B., Hamazaki, T., Ianelli, J. N., Letaw, A., Milani, K., Palof, K., Punt, A. E., Siddeek, M. S. M., Stockhausen, W., Stram, D., Szuwalski, C., Turnock, B. J., Westphal, M., & Zheng, J. (2018). Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands Regions. North Pacific Fishery Management Council. https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2018/SAFE_2018_Complete.pdf

Bédard, J. 1969a. Adaptive radiation in alcidae. *Ibis* 111:189-198.

Bédard, J. 1969b. Feeding of the least, crested, and parakeet auklets around St. Lawrence Island, Alaska. *Canadian Journal of Zoology* 47:1025-1050.

Bell, F. H. 1969. Agreements, Conventions, and Treaties Between Canada and the United States of America with Respect to the Pacific Halibut Fishery. Report of the International Pacific Halibut Commission No. 50. International Pacific Halibut Commission, Seattle, WA.

Bent, A. C. 1925. *Life Histories of North American Wild Fowl*. US National Museum, US Government Printing Office, Washington, DC.

Best, E. A. 1977. Distribution and Abundance of Juvenile Halibut in the Southeastern Bering Sea. International Pacific Halibut Commission Scientific Report No. 62. International Pacific Halibut Commission, Seattle, WA.

Best, E. A. and G. St-Pierre. 1986. Pacific Halibut as Predator and Prey. International Pacific Halibut Commission Technical Report No. 21. International Pacific Halibut Commission, Seattle, WA.

Best, E. A. and W. H. Hardman. 1982. Juvenile Halibut Surveys, 1973-1980. International Pacific Halibut Commission Technical Reports 20. International Pacific Halibut Commission, Seattle, WA.

Biderman, J. O. and W. H. Drury. 1978. Ecological Studies in the Northern Bering Sea: Studies of Seabirds in the Bering Strait. Environmental Assessment of the Alaska Continental Shelf, Annual Report of Principal Investigators. US Department of Commerce, Environmental Assessment Program, Boulder, CO.

Black, L. T. 1983. Some problems in interpretation of Aleut prehistory. *Arctic Anthropology*:49-78.

Black L. T. 2004. Russians in Alaska 1732–1867. Fairbanks: University of Alaska Press. xv + 328 p, illustrated, soft cover. ISBN 1-889963-05-4.

Blau, S. F. 1996. The 1995 St. Matthew Island blue king crab survey. Alaska Department of Fish and Game.

Bluhm, B. A. and R. Gradinger. 2008. Regional variability in food availability for Arctic marine mammals. *Ecological Applications* 18:77–96.

Bond, A. L., I. L. Jones, S. S. Seneviratne, and S. B. Muzaffar. 2013. Least Auklet (*Aethia pusilla*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/leaauk/introduction.

Bonner, N. W. 1978. Man's impact on seals. Mammal Review, 8(1–2), 3–13. https://doi.org/10.1111/j.1365-2907.1978.tb00210.x.

Bornstein, J. M., J. Adams, B. Hollebone, T. King, P. V. Hodson, and R. S. Brown. 2014. Effects-driven chemical fractionation of heavy fuel oil to isolate compounds toxic to trout embryos. Environmental Toxicology and Chemistry 33:814-824.

Bradshaw, C., L. O. Veale, A. S. Hill, A. R. Brand, C. Brand, P. Bradshaw, and A. R. Collins. 2002. *Effects of trawling and dredging on seafloor habitat*.

Bradstreet, M. S. W. 1985. Feeding studies, *In Population Estimation, Productivity, and Food Habits of Nesting Seabirds at Cape Pierce and the Pribilof Islands, Bering Sea, Alaska*. S. R. Johnson ed., pp. 257-306. LGL Ecological Research Associates, Inc. for Minerals Management Service, Anchorage, AK.

Britayev, T. A., A. V. Rzhavsky, L. V. Pavlova, and A. G. Dvoretskij. 2010. Studies on impact of the alien red king crab (*Paralithodes camtschaticus*) on the shallow water benthic communities of the Barents Sea. *Journal of Applied Ichthyology* 26:66-73.

Brodeur, R. D., M. T. Wilson, L. Ciannelli, M. Doyle, and J. M. Napp. 2002. Interannual and regional variability in distribution and ecology of juvenile pollock and their prey in frontal structures of the Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography* 49:6051-6067.

Brown, Z. W. and K. R. Arrigo. 2013. Sea ice impacts on spring bloom dynamics and net primary production in the Eastern Bering Sea. *Journal of Geophysical Research: Oceans* 118:43-62. Burger, A. E. and D. M. Fry. 1993. Effects of oil pollution on seabirds in the northeast Pacific. Canadian Wildlife Service, Ottawa, Ontario, Canada.

Burgos, J., B. Ernst, D. Armstrong, and J. Orensanz. 2013. Fluctuations in range and abundance of snow crab (*Chionoecetes opilio*) from the eastern Bering Sea: What role for Pacific cod (*Gadus macrocephalus*) predation? *Bulletin of Marine Science* 89:57-81.

Byrd, G. V. 1989. Seabirds in the Pribilof Islands, Alaska: Trends and Monitoring Methods. MS thesis, University of Idaho, Moscow, ID.

Byrd, G. V. and J. C. Williams. 1993. Whiskered Auklet (*Aethia pygmaea*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/whiauk/introduction/.

Byrd, G. V. and T. G. Tobish. 1978. Wind-caused mortality in a kittiwake colony at Buldir Island, Alaska. *Murrelet* 59:37.

Byrd, G. V., E. C. Murphy, G. W. Kaiser, A. Y. Kondratyev, and Y. V. Shibaev. 1993. Status and ecology of offshore fish-feeding alcids (murres and puffins) in the North Pacific, *In The Status, Ecology, and Conservation of Marine Birds of the North Pacific*. K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey eds., pp. 176-186. Canadian Wildlife Service, Victoria, Canada. Accessed online at http://pacificseabirdgroup.org/psg-publications/symposia/the-status-ecology-and-conservation-of-marine-birds-of-the-north-pacific/.

Calkins, D. G., K. W. Pitcher, K. B. Schneider, and N. Murray. 1982. Population assessment, ecology and trophic relationships of Steller sea lions in the Gulf of Alaska. Final Report Outer Continental Shelf Environmental Assessment Program, Research Unit 243, Contract Number 03-5-022-69. Alaska Department of Fish and Game, Anchorage, AK.

Carey, M. J., R. A. Phillips, J. R. D. Silk, and S. A. Shaffer. 2014. Trans-equatorial migration of Short-tailed Shearwaters revealed by geolocators. *Emu* 114:352-359.

Causey, D. 2002. Red-faced Cormorant (*Phalacrocorax urile*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/refcor/introduction.

Cavole, L. M., A. M. Demko, R. E. Diner, A. Giddings, I. Koester, C. M. Pagniello, M.-L. Paulsen, A. Ramirez-Valdez, S. M. Schwenck, and N. K. Yen. 2016. Biological impacts of the 2013–2015 warm-water anomaly in the northeast Pacific: Winners, losers, and the future. *Oceanography* 29:273-285.

Chuenpagdee, R., L. E. Morgan, S. M. Maxwell, E. A. Norse, and D. Pauly. 2003. Shifting gears: Assessing collateral impacts of fishing methods in US waters. *Frontiers in Ecology and the Environment* 1:517-524.

Ciannelli, L., R. D. Brodeur, and J. M. Napp. 2004. Foraging impact on zooplankton by age-0 walleye pollock (*Theragra chalcogramma*) around a front in the southeast Bering Sea. *Marine Biology* 144:515-526.

Citta, J. J., J. J. Burns, L. T. Quakenbush, V. Vanek, J. C. George, R. J. Small, M. P. Heide-Jørgensen, and H. Brower. 2014. Potential for bowhead whale entanglement in cod and crab pot gear in the Bering Sea. Marine Mammal Science 30:445-459.

Clark, W. G. and S. R. Hare. 2002. Effects of climate and stock size on recruitment and growth of Pacific halibut. *North American Journal of Fisheries Management* 22:852-862.

Corbett, D. 2016. Saĝdaĝ—To Catch Birds. *Arctic Anthropology* 53:93-113.

Coyle, K. O., A. I. Pinchuk, L. B. Eisner, and J. M. Napp. 2008. Zooplankton species composition, abundance and biomass on the eastern Bering Sea shelf during summer: The potential role of water-column stability and nutrients in structuring the zooplankton community. *Deep Sea Research Part II: Topical Studies in Oceanography* 55:1775-1791.

Coyle, K. O., A. I. Pinchuk, L. B. Eisner, and J. M. Napp. 2008. Zooplankton species composition, abundance and biomass on the eastern Bering Sea shelf during summer: The potential role of water-column stability and nutrients in structuring the zooplankton community. *Deep Sea Research Part II: Topical Studies in Oceanography* 55:1775-1791.

Coyle, K. O., L. B. Eisner, F. J. Mueter, A. I. Pinchuk, M. A. Janout, K. D. Cieciel, E. V. Farley, and A. G. Andrews. 2011. Climate change in the southeastern Bering Sea: Impacts on pollock stocks and implications for the oscillating control hypothesis. *Fisheries Oceanography* 20:139–156.

Croll, D. A., A. J. Gaston, and D. G. Noble. 1991. Adaptive loss of mass in Thick-billed Murres. *Condor* 93:496-502.

Dall, W. H. 1877. *Tribes of the extreme Northwest*. Volume 1. US Government Printing Office.

Dall W.H. 1878. Alaskan Mummies. American Naturalist. 9 (8): 433-440. (tDAR id: 109493).

Daly, B. J., C. E. Armistead, and R. J. Foy. 2016. The 2016 Eastern Bering Sea Continental Shelf Bottom Trawl Survey: Results for Commercial Crab Species. NOAA Technical Memorandum NMFS-AFSC. National Oceanic and Atmospheric Administration, Kodiak, AK.

Daly, B., G. L. Eckert, and T. D. White. 2012. Predation of hatchery-cultured juvenile red king crabs (*Paralithodes camtschaticus*) in the wild. *Canadian Journal of Fisheries and Aquatic Sciences* 70:358-366.

Davis, N. D., K. W. Myers, and Y. Ishida. 1998. Caloric value of high-seas salmon prey organisms and simulated salmon ocean growth and prey consumption. *North Pacific Anadromous Fish Commission Bulletin No. 1*:146-162.

Davis, R. W., T. M. Williams, J. A. Thomas, R. A. Kastelein, and L. H. Cornell. 1988. The effects of oil contamination and cleaning on sea otters (*Enhydra lutris*). II. Metabolism, thermoregulation, and behavior. Canadian Journal of Zoology 66:2782-2790.

Dean, T. A., Haldorson, L., Laur, D. R., Jewett, S. C., Blanchard, A. 2000. The Distribution of Nearshore Fishes in Kelp and Eelgrass Communities in Prince William Sound, Alaska: Associations with Vegetation and Physical Habitat Characteristics. Environmental Biology of Fishes, 57(3), 271–287. https://doi.org/10.1023/a:1007652730085

de Rivera, C. E., B. P. Steves, P. W. Fofonoff, A. H. Hines, and G. M. Ruiz. 2011. Potential for high-latitude marine invasions along western North America. Diversity and Distributions 17:1198-1209.

Dew, C. B. 1990. Behavioral ecology of podding red king crab, *Paralithodes camtschatica*. *Canadian Journal of Fisheries and Aquatic Sciences* 47:1944-1958.

Dew, C.B. 2010. Podding behavior of adult king crab and its effect on abundance-estimate precision, *In Biology and Management of Exploited Crab Populations Under Climate Change*. G. H. Kruse, G. L. Eckert, R. J. Foy, R. N. Lipcius, B. Sainte-Marie, D. L. Stram, and D. Woodby eds. Alaska Sea Grant, University of Alaska Fairbanks, Fairbanks, AK.

Dionne, M., B. Sainte-Marie, E. Bourget, and D. Gilbert. 2003. Distribution and habitat selection of early benthic stages of snow crab *Chionoecetes opilio*. *Marine Ecology Progress Series* 259:117-128.

Dizon, A. E., C. Lockyer, W. F. Perrin, D. P. Demaster, and J. Sisson. 1992. Rethinking the stock concept: A phylogeographic approach. *Conservation Biology* 6:24-36.

Double, M.C. 2003. “Procellariiformes (Tubenosed Seabirds)”. In Hutchins, Michael; Jackson, Jerome A.; Bock, Walter J.; Olendorf, Donna (eds.). Grzimek's Animal Life Encyclopedia. 8 Birds I Tinamous and Ratites to Hoatzins (2nd ed.). Farmington Hills, MI: Gale Group. pp. 107–111. ISBN 0-7876-5784-0.

Douglas, A. B., J. Calambokidis, S. Raverty, S. J. Jeffries, D. M. Lambourn, and S. A. Norman. 2008. Incidence of ship strikes of large whales in Washington State. Journal of the Marine Biological Association of the United Kingdom 88:1121-1132.

Dragoo, D. E. 1991. Food Habits and Productivity of Kittiwakes and Murres at St. George Island, Alaska. MS thesis, University of Alaska, Fairbanks, AK.

Eisner, L. B., J. M. Napp, K. L. Mier, A. I. Pinchuk, and A. G. Andrews, III. 2014. Climate-mediated changes in zooplankton community structure for the eastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography* 109:157-171.

Eldridge, K. A. 2016. An Analysis of Archaeofauna Recovered from a Russian Period Camp on St. Paul Island, Pribilof Islands, Alaska. *Arctic Anthropology* 53:33-51.

Elliott HW. 1880. Report on the Seal Islands of Alaska. Elliott's field-notes transmitted by him to F.A. Walker, Superintendent Tenth Census, March 31, 1880.

Elliott, H. W. 1882. *A Monograph of the Seal-Islands of Alaska*. US Commission of Fish and Fisheries, Special Bulletin 176. US Government Printing Office, Washington, DC.

Elphick, C. S. and G. L. Hunt. 1993. Variations in the distributions of marine birds with water mass in the northern Bering Sea. *Condor* 95:33-44.

Ernst, B., J. M. Orensanz, and D. A. Armstrong. 2005. Spatial dynamics of female snow crab (*Chionoecetes opilio*) in the eastern Bering Sea. *Canadian Journal of Fisheries and Aquatic Sciences* 62:250-268.

Fabry, V. J., J. B. McClintock, J. T. Mathis, and J. M. Grebmeier. 2009. Ocean acidification at high latitudes: The bellweather. *Oceanography* 22:160-171.

Fairchild, L., C. Mischler, and H. Renner. 2007. Biological Monitoring on Chowiet Island in 2006: Summary Appendices. US Fish and Wildlife Service, Homer, AK.

Fay, F. H. 1982. Ecology and biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. *North American Fauna* 74:1-279.

Fay, F. H. and J. J. Burns. 1988. Maximal feeding depths of walruses. *Arctic* 41:239-240.

Fay, F. H., G. C. Ray, and A. A. Kibal'chich. 1984. Time and location of mating and associated behavior of the Pacific walrus, *Odobenus rosmarus divergens* Illiger, *In Soviet-American Cooperative Research on Marine Mammals. Volume 1–Pinnipeds. NOAA Technical Report NATIONAL MARINE FISHERIES SERVICE 12*. F. H. Fay and G. A. Fedoseev eds., pp. 89-99. National Oceanic and Atmospheric Administration, Rockville, MD.

Finkelstein, M. E., S. Wolf, M. Goldman, D. F. Doak, P. R. Sievert, G. Balogh, and H. Hasegawa. 2010. The anatomy of a (potential) disaster: Volcanoes, behavior, and population viability of the Short-tailed Albatross (*Phoebastria albatrus*). *Biological Conservation* 143:321-331.

Firsova, L. V. 1978. Breeding biology of the Red-legged Kittiwake, *Rissa brevirostris* (Bruch), and the Common Kittiwake, *Rissa tridactyla* (Linnaeus), on the Commander Islands, *In Systematics and Biology of Rare and Little-Studied Birds*. pp. 36-45. Zoological Institute, Academy of Sciences USSR, Leningrad, USSR.

Fox, A. D. and C. Mitchell. 1997. Rafting behaviour and predator disturbance to Steller Eiders *Polysticta stelleri* in northern Norway. *Journal fuer Ornithologie* 138:103-109.

Fredin, R. A. 1985. Pacific Cod in the Eastern Bering Sea: A Synopsis. Northwest Alaska Fisheries Center Processed Report 85-05. Northwest Alaska Fisheries Center, Anchorage, AK.

Frimer, O. 1994. Autumn arrival and moult in King Eiders (*Somateria spectabilis*) at Disko, West Greenland. *Arctic* 47:137-141.

Fritz, L., K. Sweeney, R. Towell, and T. Gelatt. 2015. Steller Sea Lion Haulout and Rookery Locations in the United States for 2015-05-14 (NCEI Accession 0129877). Version 2.3. NOAA National Centers for Environmental Information. Accessed online at https://data.nodc.noaa.gov/cgi-bin/ iso?id=gov.noaa.nodc:0129877.

Gabrielson, I. N. and F. C. Lincoln. 1959. *The Birds of Alaska*. Stackpole Company and Wildlife Management Institute, Mechanicsville, PA and Washington, DC.

Gaston, A. J. and I. L. Jones. 1998. *The Auks: Alcidae*. Oxford University Press, Oxford, United Kingdom and New York, NY.

Gaston, A. J. and J. M. Hipfner. 2000. Thick-billed Murre (*Uria lomvia*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/thbmur/introduction/.

Gende, S. M., A. N. Hendrix, K. R. Harris, B. Eichenlaub, J. Nielsen, and S. Pyare. 2011. A Bayesian approach for understanding the role of ship speed in whale–ship encounters. Ecological Applications 21:2232-2240.

Gentry, R. L. 1998. *Behavior and Ecology of the Northern Fur Seal*. Princeton University Press, Princeton, NJ.

George, J. C., G. Sheffield, D. J. Reed, B. Tudor, R. Stimmelmayr, B. T. Person, T. Sformo, and R. Suydam. 2017. Frequency of injuries from line entanglements, killer whales, and ship strikes on Bering-Chukchi-Beaufort Seas bowhead whales. *Arctic* 70:37-46.

George, J. C., L. M. Philo, K. Hazard, D. Withrow, G. M. Carroll, and R. Suydam. 1994. Frequency of killer whale (*Orcinus orca*) attacks and ship collisions based on scarring on bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort Seas stock. *Arctic* 47:247-255.

Grebmeier, J. M., C. P. McRoy, and H. M. Feder. 1988. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi Seas. I. Food-supply source and benthic biomass. *Marine Ecology Progress Series* 48:57-67.

Groot, C. and L. Margolis. 1991. *Pacific Salmon Life Histories*. University of British Columbia Press, Vancouver, Canada.

Gudmundson, C. J., T. K. Zeppelin, and R. R. Ream. 2006. Application of two methods for determining diet of northern fur seals (*Callorhinus ursinus*). *Fishery Bulletin* 104:445-455.

Haney, J. C. 1991. Influence of pycnocline topography and water-column structure on marine distributions of alcids (Aves: Alcidae) in Anadyr Strait, northern Bering Sea, Alaska. *Marine Biology* 110:419-435.

Hanna, G. D. 2008. The Alaska Fur-Seal Islands. John A. Lindsay, ed. U.S. Department of Commerce, NOAA Technical Memorandum. NOS ORR 16

Harding, A. M. A. 2001. The Breeding Ecology of Horned Puffins, *Fratercula corniculata*, in Alaska. MA thesis, University of Durham, Durham, United Kingdom.

Hasegawa, H. and A. R. DeGange. 1982. The Short-tailed Albatross, *Diomedea albatrus*, its status, distribution and natural history. *American Birds* 36:806-814.

Hatch, S. A. and M. A. Hatch. 1983. Populations and habitat use of marine birds in the Semidi Islands, Alaska. *Murrelet* 64:39–46.

Hatch, S. A., G. V. Byrd, D. B. Irons, and G. L. Hunt, Jr. 1993. Status and ecology of kittiwakes (*Rissa tridactyla* and *R. brevirostris*) in the North Pacific, *In The Status, Ecology and Conservation of Marine Birds in the North Pacific*. K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey eds., pp. 140-153. Canadian Wildlife Service, Victoria, Canada. Accessed online at http://pacificseabirdgroup.org/psg-publications/symposia/the-status-ecology-and-conservation-of-marine-birds-of-the-north-pacific/.

Hayward, J. L. and N. Verbeek. 2008. Glaucous-winged gull (*Larus glaucescens*). *The Birds of North America Online* 59.

Hébert, M., E. Wade, P. DeGrâce, J.-F. Landry, and M. Moriyasu. 2014. The 2013 Assessment of the Snow Crab (*Chionoecetes opilio*) Stock in the Southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F). Research Document 2014/084. DFO Canadian Science Advisory Secretariat, Ottawa, Canada.

Heifetz, J. 2002. Coral in Alaska: Distribution, abundance, and species associations. *Hydrobiologia* 471:19-28.

Hendry, A. P. and O. K. Berg. 1999. Secondary sexual characters, energy use, senescence, and the cost of reproduction in sockeye salmon. *Canadian Journal of Zoology* 77:1663-1675.

Hickey, J. J. and F. L. Craighead. 1977. A census of the seabirds of the Pribilof Islands, *In Environmental Assessments of the Alaskan Continental Shelf, Annual Report 2*. pp. 96-195. Outer Continental Shelf Environmental Assessment Program, Boulder, CO.

Higgins, L. V., D. P. Costa, A. C. Huntley, and B. J. Boeuf. 1988. Behavioral and physiological measurements of maternal investment in the Steller sea lion, *Eumetopias jubatus*. *Marine Mammal Science* 4:44-58.

Hinckley, S. 1987. The reproductive biology of walleye pollock, *Theragra chalcogramma*, in the Bering Sea, with reference to spawning stock structure. *Fishery Bulletin* 85:481-498.

Hipfner, J. M. and G. V. Byrd. 1993. Breeding biology of the Parakeet Auklet compared to other crevice-nesting species at Buldir Island, Alaska. *Colonial Waterbirds* 16:128-138.

Hoffman, W., D. Heinemann, and J. A. Wiens. 1981. The ecology of seabird feeding flocks in Alaska. *Auk* 98:437-456.

Hood, W. R. and K. A. Ono. 1997. Variation in maternal attendance patterns and pup behavior in a declining population of Steller sea lions *(Eumetopias jubatus). Canadian Journal of Zoology* 75:1241-1246.

Hood, D.W. and J. A. Calder (Eds.). 1981. *The Eastern Bering Sea Shelf: Oceanography and Resources*. Volume 1. University Washington Press, Seattle.

Hopcroft, R., C. Ashjian, S. Smith, and K. Kosobokova. 2008. Zooplankton, *In Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research*. R. Hopcroft, B. Bluhm, R. Gradinger, T. E. Whitledge, T. Weingartner, B. Norcross, and A. Springer eds. University of Alaska Fairbanks, Institute of Marine Science, Fairbanks, AK.

Hrdlička, A. 1945. Aleutian and Commander Islands and their inhabitants.

Hunt, G. L., C. Baduini, and J. Jahncke. 2002a. Diets of short-tailed shearwaters in the southeastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography* 49:6147-6156.

Hunt, G. L., Jr, K. O. Coyle, L. B. Eisner, E. V. Farley, R. A. Heintz, F. Mueter, J. M. Napp, J. E. Overland, P. H. Ressler, S. Salo, and P. J. Stabeno. 2011. Climate impacts on eastern Bering Sea foodwebs: A synthesis of new data and an assessment of the oscillating control hypothesis. *ICES Journal of Marine Science* 68:1230–1243.

Hunt, G. L., Jr, K. O. Coyle, S. Hoffman, M. B. Decker, and E. N. Flint. 1996. Foraging ecology of Short-tailed Shearwaters near the Pribilof Islands, Bering Sea. *Marine Ecology Progress Series* 141:1-11.

Hunt, G. L., Jr, N. M. Harrison, and J. F. Piatt. 1993. Foraging ecology as related to the distribution of planktivorous auklets in the Bering Sea, *In The Status, Ecology and Conservation of Marine Birds in the North Pacific*. K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey eds., pp. 18-26. Canadian Wildlife Service, Victoria, British Columbia. Accessed online at http://pacificseabirdgroup.org/psg-publications/symposia/the-status-ecology-and-conservation-of-marine-birds-of-the-north-pacific/.

Hunt, G. L., Jr, P. J. Gould, D. J. Forsell, and H. Peterson, Jr. 1981. Pelagic distribution of marine birds in the eastern Bering Sea, *In The Eastern Bering Sea Shelf: Oceanography and Resources*. D. W. Hood and J. A. Calder eds., pp. 689-718. National Oceanic and Atmospheric Administration, Seattle, WA.

Hunt, G. L., Jr, P. J. Stabeno, S. Strom, and J. M. Napp. 2008. Patterns of spatial and temporal variation in the marine ecosystem of the southeastern Bering Sea, with special reference to the Pribilof Domain. *Deep Sea Research II* 55:1919-1944.

Hunt, G. L., Jr, P. Stabeno, G. Walters, E. Sinclair, R. D. Brodeur, J. M. Napp, and N. A. Bond. 2002b. Climate change and control of the southeastern Bering Sea pelagic ecosystem. *Deep Sea Research Part II: Topical Studies in Oceanography* 49:5821-5853.

Hunt, G. L., Jr, R. W. Russell, K. O. Coyle, and T. Weingartner. 1998. Comparative foraging ecology of planktivorous auklets in relation to ocean physics and prey availability. *Marine Ecology Progress Series* 167:241-259.

Ianelli, J. N., S. J. Barbeaux, and D. McKelvey. 2016. Assessment of walleye pollock in the Bogoslof Island region, *In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions for 2017*. pp. 301-310. North Pacific Fishery Management Council, Anchorage, AK.

Jemison, L. A., G. W. Pendleton, L. W. Fritz, K. K. Hastings, J. M. Maniscalco, A. W. Trites, and T. S. Gelatt. 2013. Inter-population movements of Steller sea lions in Alaska with implications for population separation. *PLoS ONE* 8:e70167.

Jensen, G. C. and D. A. Armstrong. 1989. Biennial reproductive cycle of blue king crab, *Paralithodes platypus*, at the Pribilof Islands, Alaska and comparison to a congener, *P. camtschatica Canadian Journal of Fisheries and Aquatic Sciences* 46:932-940.

Jenssen, B. M. 1994. Review article: Effects of oil pollution, chemically treated oil, and cleaning on thermal balance of birds. Environmental Pollution 86:207-215.

Jochelson, W. 1925. Archaeological Investigations in the Aleutian islands: Publication/Carnegie Institution of Washington.

Jochelson, W. 2002. History, Ethnology and Anthropology Of The Aleut (Anthropology of Pacific North America). University of Utah Press.

John, K. B. F. and M. E. Graeme. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. *Marine Ecology Progress Series* 316:185-199.

Johnsgard, P. A. 1964. Comparative behavior and relationships of the eiders. *Condor* 66:113-129.

Johnson, A. M. 1968. Annual mortality of territorial male fur seals and its management significance. *Journal of Wildlife Management* 32:94-99.

Johnson, S. R. and G. C. West. 1975. Growth and development of heat regulation in nestlings, and metabolism of adult Common and Thick-billed Murres. *Ornis Scandinavica* 6:109-115.

Johnson, S. R. and J. S. Baker. 1985. Population Estimation, Productivity, and Food Habits of Nesting Seabirds at Cape Pierce and the Pribilof Islands, Bering Sea, Alaska. US Minerals Management Service, Anchorage, AK.

Jones, I. L. 1993. Crested Auklet (*Aethia cristatella*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/creauk/introduction/.

Jones, I. L. and R. Montgomerie. 1992. Least Auklet ornaments: Do they function as quality indicators? *Behavioral Ecology and Sociobiology* 30:43-52.

Jones, I. L., N. B. Konyukhov, J. C. Williams, and G. V. Byrd. 2001. Parakeet Auklet (*Aethia psittacula*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/parauk/introduction.

Jones, T., L. M. Divine, H. Renner, S. Knowles, K. A. Lefebvre, H. K. Burgess, C. Wright, and J. K. Parrish. 2019. Unusual mortality of Tufted puffins (*Fratercula cirrhata*) in the eastern Bering Sea. *PLoS ONE* 14.

Kajimura, H. and T. R. Loughlin. 1988. Marine mammals in the oceanic food web of the eastern subarctic Pacific. *Bulletin of the Ocean Research Institute* 26:187-223.

Kastelein, R. A. 2009. Walrus (*Odobenus rosmarus*), *In Encyclopedia of Marine Mammals*. W. F. Perrin, B. Würsig, and J. G. M. Thewissen eds., pp. 1294-1300. Academic Press, Burlington, MA.

Kaufman, K. 1989. Black-legged Kittiwake and Red-legged Kittiwake. *American Birds* 43:3-7.

Kawaguchi, S., H. Kurihara, R. King, L. Hale, T. Berli, J. P. Robinson, A. Ishida, M. Wakita, P. Virtue, S. Nicol, and A. Ishimatsu. 2010. Will krill fare well under Southern Ocean acidification? *Biology Letters* 7:228-291.

Kenter, J.O., Reed, M., Fazey, I., 2016a. The deliberative value formation model. Ecosyst. Serv. 21, 194–207.

Kenter, J.O., Reed, M.S., Irvine, K.N., O'Brien, E., Bryce, R., Christie, M., Cooper, N., Hockley, N., Fazey, I., Orchard-Webb, J., Ravenscroft, N., Raymond, C.M., Tett, P., Watson, V., 2016 b. Shared values and deliberative valuation: future directions. Ecosyst. Serv. 21, 358–371.

Kenyon, K.W. 1962. History of the Steller Sea Lion at the Pribilof Islands, Alaska. Journal of Mammalogy, 43(1), 68-75. doi:10.2307/1376881

Kenyon, K. W. and D. W. Rice. 1961. Abundance and distribution of the Steller sea lion. *Journal of Mammalogy* 42:223-234.

Kenyon, K. W. and R. E. Phillips. 1965. Birds from the Pribilof Islands and vicinity. *Auk* 82:624-635.

Kim, S, L. and Oliver, J. 2011. Swarming benthic crustaceans in the Bering and Chukchi seas and their relation to geographic patterns in gray whale feeding. Canadian Journal of Zoology. 67. 1531-1542. 10.1139/z89-218.

Knowlton, A. R. and S. D. Kraus. 2001. Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. Journal of Cetacean Research and Management (special issue) 2:193-208.

Knudtson, E. P. and G. V. Byrd. 1982. Breeding biology of Crested, Least, and Whiskered Auklets on Buldir Island, Alaska. *Condor* 84:197-202.

Kokubun, N., T. Yamamoto, D. M. Kikuchi, A. Kitaysky, and A. Takahashi. 2015. Nocturnal foraging by Red-legged Kittiwakes, a surface feeding seabird that relies on deep water prey during reproduction. *PLoS ONE* 10:e0138850.

Kon, T., M. Ono, and Y. Honma. 2010. Histological studies on the spent ovaries of aged snow crabs *Chionoecetes opilio* caught in the Sea of Japan. *Fisheries Science* 76:227-233.

Kondratyev, A. Y., P. S. Vyatkin, and Y. V. Shibaev. 2000. Conservation and protection of seabirds and their habitat, *In Seabirds of the Russian Far East*. A. V. Kondratyev, N. M. Litvinenko, and G. W. Kaiser eds., pp. 117-129. Canadian Wildlife Service Special Publication, Ottawa, Canada.

Kovacs, K. M. and C. Lydersen. 2008. Climate change impacts on seals and whales in the North Atlantic Arctic and adjacent shelf seas. *Science Progress* 91:117-150.

Kuhn, C. E., R. R. Ream, J. T. Sterling, J. R. Thomason, and R. G. Towell. 2014. Spatial segregation and the influence of habitat on the foraging behavior of northern fur seals (*Callorhinus ursinus*). *Canadian Journal of Zoology* 92:861-873.

Kuletz, K. J., M. Renner, E. A. Labunski, and G. L. Hunt. 2014. Changes in the distribution and abundance of albatrosses in the eastern Bering Sea: 1975–2010. *Deep Sea Research Part II: Topical Studies in Oceanography* 109:282–292.

Kuro-o, M., H. Yonekawa, S. Saito, M. Eda, H. Higuchi, H. Koike, and H. Hasegawa. 2010. Unexpectedly high genetic diversity of mtDNA control region through severe bottleneck in vulnerable albatross *Phoebastria albatrus*. *Conservation Genetics* 11:127-137.

Laevastu, T. and F. Favorite. 1988. *Fishing and Stock Fluctuation*. Fishing Books Ltd, Farnham, United Kingdom.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet, and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science 17:35-75.

Lamothe, P. 1973. Biology of King Eider (*Somateria spectabilis*) in a Fresh Water Breeding Area on Bathurst Island, NWT. MS thesis, University of Alberta, Edmonton, Canada.

Lander, R. H. 1981. A life table and biomass estimate for Alaskan fur seals. *Fisheries Research* 1:55-70.

Lantis, M. 1970. The Aleut social system, 1750 to 1810, from early historical sources. *Ethnohistory in southwestern Alaska and the southern Yukon: Method and content*:139-301.

Lantis, M. A. and D. Damas. 1984. IN Handbook of North American Indians, Volume 5: Arctic. *Washington DC: Smithsonian Institution*.

Laughlin, W. S. 1980. *Aleuts, survivors of the Bering land bridge*. Holt Rinehart & Winston.

Laurel, B. J., A. W. Stoner, C. H. Ryer, T. P. Hurst, and A. A. Abookire. 2007. Comparative habitat associations in juvenile Pacific cod and other gadids using seines, baited cameras and laboratory techniques. *Journal of Experimental Marine Biology and Ecology* 351:42-55.

Laurel, B. J., M. Spencer, P. Iseri, and L. A. Copeman. 2016. Temperature-dependent growth and behavior of juvenile Arctic cod (*Boreogadus saida*) and co-occurring North Pacific gadids. *Polar Biology* 39:1127-1135.

Lea, S., B. Felver, G. Landini, and A. Walmsley. 2009. Ultrasonic scaler oscillations and tooth-surface defects. *Journal of dental research* 88:229-234.

Lestenkof P.M., P.I, Melovidov, A.P. Lestenkof, L.M. Divine. 2018. The subsistence harvest of Steller sea lions on St. Paul Island, Alaska from 2005 – 2016. 33 pp. Available from the Ecosystem Conservation Office upon request.

Leu, E., Mundy, C., Assmy, P., Campbell, K., Gabrielsen, T., Gosselin, M., Juul-Pedersen, T., Gradinger, R. 2015. Arctic spring awakening - Steering principles behind the phenology of vernal ice algal blooms. Progress In Oceanography. 139. 151-170. 10.1016/j.pocean.2015.07.012.

Levermann, N., A. Galatius, G. Ehlme, S. Rysgaard, and E. W. Born. 2003. Feeding behaviour of free-ranging walruses with notes on apparent dextrality of flipper use. *BMC Ecology* 3:9.

Livingston, P. A. 1989. Interannual trends in Pacific cod, *Gadus marcocephalus*, predation on three commercially important crab species in the eastern Bering Sea. *Fisheries Bulletin* 87:807-827.

Livingston, P. A. 1991. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984–1986. NOAA Technical Memorandum, National Marine Fisheries Service, F/NWC-207. National Oceanic and Atmospheric Administration, Seattle, WA.

Livingston, P. A. 1993. Importance of predation by groundfish, marine mammals and birds on walleye pollock *Theragra chalcogramma* and Pacific herring *Clupea pallasi* in the eastern Bering Sea. *Marine Ecology Progress Series* 102:205-215.

Lloyd, D. S. 1985. Breeding Performance of Kittiwakes and Murres in Relation to Oceanographic and Meteorologic Conditions Across the Shelf of the Southeastern Bering Sea. MS thesis, University of Alaska, Fairbanks, AK.

Long, W. C., K. M. Swiney, C. Harris, H. N. Page, and R. J. Foy. 2013. Effects of ocean acidification on juvenile red king crab (*Paralithodes camtschaticus*) and tanner crab (*Chionoecetes bairdi*) growth, condition, calcification, and survival. *PLoS ONE* 8:e60959.

Loughlin, T. R., D. J. Rugh, and C. H. Fiscus. 1984. Northern sea lion distribution. *Journal of Wildlife Management* 48:729-740.

Loughlin, T. R., W. J. Ingraham, Jr, N. Baba, and B. W. Robson. 1999. Use of a surface current model and satellite telemetry to assess marine mammal movements in the Bering Sea, *In Dynamics of the Bering Sea*. T. R. Loughlin and K. Ohtani eds., pp. 615-630. University of Alaska Sea Grant Press, AK-SG-99-03, Fairbanks, AK.

Lovrich, G. A. and B. Sainte-Marie. 1997. Cannibalism in the snow crab, *Chionoecetes opilio* (O. Fabricius) (Brachyura: Majidae), and its potential importance to recruitment. *Journal of Experimental Marine Biology and Ecology* 211:225-245.

Lunn, N., I. Boyd, T. Barton, and J. Croxall. 1993. Factors affecting the growth rate and mass at weaning of Antarctic fur seals at Bird Island, South Georgia. *Journal of Mammalogy* 74:908-919.

Lyons, C., G. Eckert, and A. W. Stoner. 2016. Influence of temperature and congener presence on habitat preference and fish predation in blue (*Paralithodes platypus*) and red (*P. camtschaticus tilesius*, 1815) king crabs (Anomura: Lithodidae). *Journal of Crustacean Biology* 36:12-22.

MacDonald, S. O. and J. A. Cook. 2009. *Recent Mammals of Alaska*. University of Alaska Press, Fairbanks, AK.

Magnuson-Stevens Fishery Conservation and Management Act, as Amended Through January 12, 2007. Public Law 94-265. (2007).

Malecha, P. W., R. P. Stone, and J. Heifetz. 2005. Living substrate in Alaska: Distribution, abundance, and species associations, *In Benthic Habitats and the Effects of Fishing*. P. W. Barnes and J. P. Thomas eds., pp. 289-299. American Fisheries Society Symposium 41, Bethesda, MD.

Marschall, E. A., T. P. Quinn, D. A. Roff, J. A. Hutchings, N. B. Metcalfe, T. A. Bakke, R. L. Saunders, and N. L. Poff. 1998. A framework for understanding Atlantic salmon (*Salmo salar*) life history. *Canadian Journal of Fisheries and Aquatic Sciences* 55:48-58.

McCartney, A. P. 1984. Prehistory of the Aleutian region. *Handbook of North American Indians: Arctic*.

McCaughran, D. A. and G. C. Powell. 1977. Growth model for Alaska king crab (*Paralithodes camtschaticus*). *Journal of the Fisheries Research Board of Canada* 34:989-995.

McConnaughey, R. A., K. L. Mier, and C. B. Dew. 2000. An examination of chronic trawling effects on soft-bottom benthos of the eastern Bering Sea. *ICES Journal of Marine Science* 57:1377-1388.

McDermond, D. K. and K. Morgan. 1993. Status and conservation of North Pacific albatrosses, *In The Status, Ecology, and Conservation of Marine Birds of the North Pacific*. K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey eds., pp. 70-81. Canadian Wildlife Service, Victoria, Canada. Accessed online at http://pacificseabirdgroup.org/psg-publications/symposia/the-status-ecology-and-conservation-of-marine-birds-of-the-north-pacific/.

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson. 2002. *Fishes of Alaska*. American Fisheries Society, Bethesda, MD.

Merkel, F. R., A. Mosbech, S. E. Jamieson, and K. Falk. 2007b. The diet of King Eiders wintering in Nuuk, southwest Greenland, with reference to sympatric wintering Common Eiders. *Polar Biology* 30:1593-1597.

Merkel, F. R., S. E. Jamieson, K. Falk, and A. Mosbech. 2007a. The diet of Common Eiders wintering in Nuuk, southwest Greenland. *Polar Biology* 30:227-234.

Merrick, R. L., M. K. Chumbley, and G. V. Byrd. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: A potential relationship. *Canadian Journal of Fisheries and Aquatic Sciences* 54:1342-1348.

Miller, C. N. 2014. Milk Fatty Acid Composition of Perinatal and Foraging Steller Sea Lions: Examination from Pup Stomachs. PhD thesis, University of Alaska Fairbanks, Fairbanks, AK.

Minami, H., M. Minagawa, and H. Ogi. 1995. Changes in stable carbon and nitrogen isotope ratios in Sooty and Short-tailed Shearwaters during their northward migration. *Condor* 97:565-574.

Moore, S. E. and J. T. Clarke. 2002. Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). Journal of Cetacean Research and Management 4:19-25.

Moore, S. E., R. R. Reeves, B. L. Southall, T. J. Ragen, R. S. Suydam, and C. W. Clark. 2012. A new framework for assessing the effects of anthropogenic sound on marine mammals in a rapidly changing Arctic. BioScience 62:289-295.

Moriyasu, M. and P. Mallet. 1986. Molt stages of the snow crab *Chionoecetes opilio* by observation of morphogenesis of setae on the maxilla. *Journal of Crustacean Biology* 6:709-718.

Morrison, K., J. M. Hipfner, C. Gjerdrum, and D. Green. 2009. Wing length and mass at fledging predict local juvenile survival and age at first return in Tufted Puffins. *Condor* 111:433-441.

Moss, J. H., M. F. Zaleski, and R. A. Heintz. 2016. Distribution, diet, and energetic condition of age-0 walleye pollock (*Gadus chalcogrammus*) and Pacific cod (*Gadus macrocephalus*) inhabiting the Gulf of Alaska. *Deep Sea Research Part II: Topical Studies in Oceanography* 132:146-153.

Moukhametov, I. N., A. M. Orlov, and B. M. Leaman. 2008. Diet of Pacific Halibut (*Hippoglossus stenolepis*) in the Northwestern Pacific Ocean. Technical Report No. 52. International Pacific Halibut Commission, Seattle, WA.

Munk, K. M. 2001. Maximum ages of groundfishes in waters off Alaska and British Columbia and considerations of age determination. *Alaska Fishery Research Bulletin* 8:12-21.

Murie, O. J. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. *North American Fauna* 61:1-364.

Murphy, E. C. and J. H. Schauer. 1996. Synchrony in egg-laying and reproductive success of neighboring Common Murres, *Uria aalge*. *Behavioral Ecology and Sociobiology* 39:245-258.

Muto MM, VT Helker, RP Angliss, BA Allen, PL Boveng, JM Breiwick, MF Cameron, et al. 2017. Alaska Marine Mammal Stock Assessments, 2017. NOAA Tech Memo NMFS-AFSC-378: 37-52.

Nahrgang, J., P. Dubourg, M. Frantzen, D. Storch, F. Dahlke, and J. P. Meador. 2016. Early life stages of an Arctic keystone species (*Boreogadus saida*) show high sensitivity to a water-soluble fraction of crude oil. Environmental Pollution 218:605-614.

National Marine Fisheries Service. 2004. Programmatic Supplemental Environmental Impact Statement for the Alaska Groundfish Fisheries Implemented Under the Authority of the Fishery Management Plans for the Groundfish Fishery of the Gulf of Alaska and the Groundfish of the Bering Sea and Aleutian Islands Area. National Marine Fisheries Service, Juneau, AK and Seattle, WA.

National Marine Fisheries Service. 2007. Conservation Plan for the Eastern Pacific Stock of Northern Fur Seal (*Callorhinus ursinus*). National Marine Fisheries Service, Juneau, AK.

National Marine Fisheries Service. 2016. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. National Oceanic and Atmospheric Administration, Silver Spring, MD.

National Oceanic and Atmospheric Administration. 2002. Final Restoration Plan and Environmental Assessment for the M/V *Kuroshima* Oil Spill. National Oceanic and Atmospheric Administration Damage Assessment Center, Seattle, WA.

National Oceanic and Atmospheric Administration. 2004. History of Alaska Groundfish Fisheries and Management Practices. Alaska Groundfish Fisheries Programmatic Supplemential Environmental Impact Statement. National Oceanic and Atmospheric Administration, Juneau, AK.

National Oceanic and Atmospheric Administration. 2017. Arctic Trajectory Analysis Planner. NOAA Office of Response and Restoration and NOAA Restoration Center, Seattle, WA.

National Research Council. 2014. Responding to Oil Spills in the US Arctic Marine Environment. National Academy of Sciences, Washington, DC.

Neidetcher, S. K., T. P. Hurst, L. Ciannelli, and E. A. Logerwell. 2014. Spawning phenology and geography of Aleutian Islands and eastern Bering Sea Pacific cod (*Gadus macrocephalus*). *Deep Sea Research Part II: Topical Studies in Oceanography* 109:204-214.

Neilson, J. L., C. M. Gabriele, A. S. Jensen, K. Jackson, and J. M. Straley. 2012. Summary of reported whale-vessel collisions in Alaskan waters. Journal of Marine Biology 2012.

Nelson, E. W., F. W. True, T. H. Bean, and W. H. Edwards. 1887. *Report Upon Natural History Collections Made in Alaska: Between the Years 1877 and 1881*. US Government Printing Office, Washington, DC.

North Pacific Anadromous Fish Commission. 2003. Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean. North Pacific Anadromous Fish Commission, Vancouver, Canada.

North Pacific Fishery Management Council. 2010. Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, AK.

North Pacific Fishery Management Council. 2011. Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, AK.

North Pacific Fishery Management Council. 2014. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands Area: Economic Status of the Groundfish Fisheries Off Alaska, 2013. North Pacific Fishery Management Council, Anchorage, AK.

North Pacific Fishery Management Council. 2015. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, AK.

North Pacific Fishery Management Council. 2015a. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands Area: Economic Status of the Groundfish Fisheries Off Alaska, 2014. North Pacific Fishery Management Council, Anchorage, AK.

North Pacific Fishery Management Council. 2015b. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, AK.

Nowacek, D. P., L. H. Thorne, D. W. Johnston, and P. L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mammal Review 37:81-115.

Nysewander, D. R. 1983. Cormorants (*Phalacrocorax* spp.), *In The Breeding Biology and Feeding Ecology of Marine Birds in the Gulf of Alaska*. P. A. Baird and P. J. Gould eds., pp. 207-236. Outer Continental Shelf Environmental Assessment Program Final Report 45. National Oceanic and Atmospheric Administration, Anchorage, AK.

Ocean Conservancy. 2017. Navigating the North: An Assessment of the Environmental Risks of Arctic Vessel Traffic. Anchorage, AK.

Ohashi, R., A. Yamaguchi, K. Matsuno, R. Saito, N. Yamada, A. Iijima, N. Shiga, and I. Imai. 2013. Interannual changes in the zooplankton community structure on the southeastern Bering Sea shelf during summers of 1994–2009. *Deep Sea Research Part II: Topical Studies in Oceanography* 94:44-56.

Oppel, S. 2009. Satellite Telemetry of King Eiders from Northern Alaska, 2002-2009. OBIS-SeaMap. Accessed online at http://seamap.env.duke.edu/.

Oppel, S. and A. N. Powell. 2010. Age-specific survival estimates of King Eiders derived from satellite telemetry. *Condor* 112:323-330.

Oppel, S., A. N. Powell, and D. L. Dickson. 2008. Timing and distance of King Eider migration and winter movements. *Condor* 110:296-305.

Oppel, S., A. N. Powell, and M. G. Butler. 2011. King Eider foraging effort during the pre-breeding period in Alaska. *Condor* 113:52-60.

Oppel, S., D. L. Dickson, and A. N. Powell. 2009. International importance of the eastern Chukchi Sea as a staging area for migrating King Eiders. *Polar Biology* 32:775-783.

Orensanz, J., B. Ernst, D. A. Armstrong, P. Stabeno, and P. Livingston. 2004. Contraction of the geographic range of distribution of snow crab (*Chionoecetes opilio*) in the eastern Bering Sea: An environmental ratchet? *California Cooperative Oceanic Fisheries Investigations* 45:65-79.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, and F. Joos. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437:681-686.

Osgood, W. H., E. A. Preble, and G. H. Parker. 1915. *The fur seals and other life of the Pribilof Islands, Alaska, in 1914*. Govt. print. off.

Palmer, R. S. 1962. *Handbook of North American Birds*. Volume 1: Loons through Flamingos. Yale University Press, New Haven, CT.

Palmer, R. S. 1976. *Handbook of North American Birds*. Volume 1–3. Yale University Press, New Haven, CT.

Parker, P. and J. M. Maniscalco. 2014. A long-term study reveals multiple reproductive behavior strategies among territorial adult male Steller sea lions (*Eumetopias jubatus*). *Canadian Journal of Zoology* 92:405-415.

Patten, S. M. 1974. Breeding ecology of the glaucous-winged gull (*Larus glaucescens*) in Glacier Bay, Alaska. MS thesis, University of Washington, Seattle.

Pelland, N. A., J. T. Sterling, M.-A. Lea, N. A. Bond, R. R. Ream, C. M. Lee, and C. C. Eriksen. 2014. Fortuitous encounters between seagliders and adult female northern fur seals (*Callorhinus ursinus*) off the Washington (USA) coast: Upper ocean variability and links to top predator behavior. *PLoS ONE* 9:e101268.

Peng, C., X. Zhao, and G. Liu. 2015. Noise in the sea and its impacts on marine organisms. International Journal of Environmental Research and Public Health 12:12304-12323.

Perez, M. A. and W. B. McAlister. 1993. Estimates of Food Consumption by Marine Mammals in the Eastern Bering Sea. NOAA Technical Memorandum NMFS-AFSC-14. National Oceanic and Atmospheric Administration, Seattle, WA.

Peterson, C. H., S. D. Rice, J. W. Short, D. Esler, J. L. Bodkin, B. E. Ballachey, and D. B. Irons. 2003. Long-term ecosystem response to the *Exxon Valdez* oil spill. *Science* 302:2082-2086.

Piatt, J. F. and A. M. Springer. 2003. Advection, pelagic food webs, and the biogeography of seabirds in Beringia. *Marine Ornithology* 31:141–154.

Piatt, J. F. and D. N. Nettleship. 1985. Diving depths of four alcids. *Auk* 102:293-297.

Piatt, J. F., A. Pinchuk, A. Kitayski, A. M. Springer, and S. A. Hatch. 1992. Foraging Distribution and Feeding Ecology of Seabirds at the Diomede Islands, Bering Strait. US Fish and Wildlife Service Final Report. OCS Study MMS 92-0041. Minerals Management Service, Anchorage, AK.

Piatt, J. F. and A. S. Kitaysky. 2002a. Horned Puffin (*Fratercula corniculata*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/horpuf/introduction/.

Piatt, J. F., and A. S. Kitaysky. 2002b. Tufted Puffin (*Fratercula cirrhata*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/tufpuf/introduction.

Piatt, J. F., B. D. Roberts, W. W. Lidster, J. L. Wells, and S. A. Hatch. 1990. Effects of human disturbance on breeding Least and Crested Auklets at St. Lawrence Island, Alaska. *Auk* 107:342-350.

Piatt, J. F., J. Wetzel, K. Bell, A. R. DeGange, G. R. Balogh, G. S. Drew, T. Geernaert, C. Ladd, and G. V. Byrd. 2006. Predictable hotspots and foraging habitat of the endangered Short-tailed Albatross (*Phoebastria albatrus*) in the North Pacific: Implications for conservation. *Deep Sea Research Part II: Topical Studies in Oceanography* 53:387–398.

Pikitch, E., C. Santora, E. Babcock, A. Bakun, R. Bonfil, D. Conover, P. Dayton, et al., P. Doukakis, D. Fluharty, and B. Heneman. 2004. Ecosystem-based fishery management. American Association for the Advancement of Science.

Pirtle, J. L. and A. W. Stoner. 2010. Red king crab (*Paralithodes camtschaticus*) early post-settlement habitat choice: Structure, food, and ontogeny. *Journal of Experimental Marine Biology and Ecology* 393:130-137.

Pitcher, K. W. and D. G. Calkins. 1981. Reproductive biology of Steller sea lions in the Gulf of Alaska. *Journal of Mammalogy* 62:599-605.

Plagányi, É. E. and D. S. J. E. A. Butterworth. 2012. The Scotia Sea krill fishery and its possible impacts on dependent predators: modeling localized depletion of prey. 22:748-761.

Pollom, E. L., J. P. Gorey, and M. D. Romano. 2018. Biological monitoring at St. George Island, Alaska in 2017. U.S. Fish and Wildlife Service. Rep., AMNWR 2018/01. Homer, Alaska.

Powell, A. N. and R. S. Suydam. 2012. King Eider (*Somateria spectabilis*), *In The Birds of North America Online*. P. G. Rodewald ed. Cornell Lab of Ornithology, Ithaca, NY. Accessed online at https://birdsna.org/Species-Account/bna/species/kineid/introduction.

Preble, E. A. and W. L. McAtee. 1923. A biological survey of the Pribilof Islands, Alaska. *North American Fauna* 46.

Punt, A. E., R. J. Foy, M. G. Dalton, W. C. Long, and K. M. Swiney. 2016. Effects of long-term exposure to ocean acidification conditions on future southern Tanner crab (*Chionoecetes bairdi*) fisheries management. *ICES Journal of Marine Science* 73:849-864.

Ragen, T.J., Antonelis, G.A., Kiyota, M., 1995. Early migration of northern fur seal pups from St. Paul Island, Alaska. Journal of Mammalogy 76 (4), 1137–1148.

Ragen, T. J., G. A. Antonelis, and M. Kiyota. 1995. Early migration of northern fur seal pups from St. Paul Island, Alaska. *Journal of Mammalogy* 76:1137-1148.

Raikow, R. J., L. Bicanovsky, and A. H. Bledsoe. 1988. Forelimb joint mobility and the evolution of wing-propelled diving in birds. *Auk* 105:446-451.

Rand, K. M., P. Munro, S. K. Neidetcher, and D. G. Nichol. 2014. Observations of seasonal movement from a single tag release group of Pacific cod in the eastern Bering Sea. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 6:287-296.

Raum-Suryan, K. L., K. W. Pitcher, D. G. Calkins, J. L. Sease, and T. R. Loughlin. 2002. Dispersal, rookery fidelity, and metapopulation structure of Steller sea lions *(Eumetopias jubatus)* in an increasing and decreasing population in Alaska. *Marine Mammal Science* 18:746-764.

Ream, R. R., J. Sterling, and T. R. Loughlin. 2005. Oceanographic features related to northern fur seal migratory movement. *Deep Sea Research Part II: Topical Studies in Oceanography* 52:823-843.

Richardson, W. J. 1995. Marine Mammals and Noise. Academic Press, San Diego, CA.

Robertson, I. 1971. Influence of Brood-size on Reproductive Success of Two Species of Cormorant, *Phalacrocorax auritus* & *P. pelagicus*, and Its Relation to the Problem of Clutch-size. MS thesis, University of British Columbia, Vancouver, Canada.

Robson, B. W., M. E. Goebel, J. D. Baker, R. R. Ream, T. R. Loughlin, R. C. Francis, G. A. Antonelis, and D. P. Costa. 2004. Separation of foraging habitat among breeding sites of a colonial marine predator, the northern fur seal (*Callorhinus ursinus*). *Canadian Journal of Zoology* 82:20-29.

Rocque, D. 2006. Impacts of Oil Spills on Unalaska Island Marine Mammals, In The *Selendang Ayu* Oil Spill: Lessons Learned, Conference Proceedings. R. Brewer ed., pp. 42-46. Alaska Sea Grant College Program, University of Alaska Fairbanks, Fairbanks, AK.

Roelke, M. and G. Hunt. 1978. Cliff attendance, foraging patterns and post-fledging behaviour of known-sex adult Thick-billed Murres (*Uria lomvia*). *Pacific Seabird Group* 5:81.

Rooper, C. N., M. E. Wilkins, C. S. Rose, and C. Coon. 2011. Modeling the impacts of bottom trawling and the subsequent recovery rates of sponges and corals in the Aleutian Islands, Alaska. *Continental Shelf Research* 31:1827-1834.

Rooper, C. N., P. J. Etnoyer, K. L. Stierhoff, and J. V. Olson. 2016. Chapter 4: Effects of fishing gear on deep-sea corals and sponges in US waters, *In State of Deep-Sea Coral and Sponge Ecosystems of the United States*. T. F. Hourigan, P. J. Etnoyer, and S. D. Cairns eds., pp. 4-1–4-19. National Oceanic and Atmospheric Administration, Silver Spring, MD.

Ropeik, A. 2014. 10 Years On, Selendang Ayu Spill's Legacy Still Evolving. Alaska Public Media.

Rubicz, R. C. 2007. Evolutionary consequences of recently founded Aleut communities in the Commander and Pribilof Islands.thesis, University of Kansas.

Rugen, R. C. and A. C. Matarese. 1988. Spatial and Temporal Distribution and Relative Abundance of Pacific Cod (*Gadus macrocephalus*) Larvae in the Western Gulf of Alaska. Northwest and Alaska Fisheries Center Processed Report 88-18. National Marine Fisheries Service, Seattle, WA.

Sanford, R. C. and S. W. Harris. 1967. Feeding behavior and food-consumption rates of a captive California Murre. *Condor* 69:298-302.

Scheffer, V. B. 1946. How deep will a fur seal dive? *The Murrelet* 27:25-25.

Schneider, D. and G. L. Hunt, Jr. 1984. A comparison of seabird diets and foraging distribution around the Pribiliof Islands, Alaska, *In Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships: Proceedings of the Pacific Seabird Group Symposium, Seattle, WA*. D. N. Nettleship, G. A. Sanger, and P. F. Springer eds., pp. 86-95. Canadian Wildlife Service, Environment Canada, Ottawa, Canada.

Schneider, D. C. and V. P. Shuntov. 1993. The trophic organization of the marine bird community in the Bering Sea. *Reviews in Fisheries Science* 1:311-335.

Schroeder, R. F., D. B. Andersen, R. Bosworth, J. M. Morris, and J. M. Wright. 1987. Subsistence in Alaska: arctic, interior, southcentral, southwest, and western regional summaries. *Technical paper* 150.

Seabird Information Network. 2017. North Pacific Seabird Data Portal. Accessed online at http://axiom.seabirds.net/maps/north-pacific-seabirds/.

Sealy, S. G. 1973. Breeding biology of the Horned Puffin on St. Lawrence Island, Bering Sea, with zoogeographical notes on the North Pacific puffins. *Pacific Science* 27:99-119.

Seneviratne, S. S. and I. L. Jones. 2008. Mechanosensory function for facial ornamentation in the Whiskered Auklet, a crevice-dwelling seabird. *Behavioral Ecology* 19:784-790.

Shaffer, S. A., Y. Tremblay, H. Weimerskirch, D. Scott, D. R. Thompson, P. M. Sagar, H. Moller, G. A. Taylor, D. G. Foley, B. A. Block, and D. P. Costa. 2006. Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. *Proceedings of the National Academy of Sciences* 103:12799-12802.

Shuntov, V. P. 2000. Seabird distribution in the marine domain, *In Seabirds of the Russian Far East*. A. V. Kondratyev, N. M. Litvinenko, and G. W. Kaiser eds., pp. 83-104. Canadian Wildlife Service Special Publication, Ottawa, Canada.

Siddon, E. C., T. Kristiansen, F. J. Mueter, K. K. Holsman, R. A. Heintz, and E. V. Farley. 2014. Spatial match-mismatch between juvenile fish and prey provides a mechanism for recruitment variability across contrasting climate conditions in the eastern Bering Sea. *PLoS ONE* 8:e84526.

Sigler, M. F., D. J. Tollit, J. J. Vollenweider, J. F. Thedinga, D. J. Csepp, J. N. Womble, M. A. Wong, M. J. Rehberg, and A. W. Trites. 2009. Steller sea lion foraging response to seasonal changes in prey availability. *Marine Ecology Progress Series* 388:243-261.

Sigler, M. F., F. J. Mueter, B. A. Bluhm, M. S. Busby, E. D. Cokelet, S. L. Danielson, A. De Robertis, L. B. Eisner, E. V. Farley, K. Iken, K. J. Kuletz, R. R. Lauth, E. A. Logerwell, and A. I. Pinchuk. 2016. Late Summer Open Water Zoogeography of the Northern Bering and Chukchi Seas. OCS Study BOEM 2011-AK-11-08 a/b. Bureau of Ocean Energy Management, Alaska OCS Region, Anchorage, AK.

Sigler, M. F., P. J. Stabeno, L. B. Eisner, J. M. Napp, and F. J. Mueter. 2014. Spring and fall subarctic ecosystem, the eastern Bering Sea, during 1995-2011. *Deep Sea Research II* 109:71-83.

Silber, G. K. and S. O. M. Bettridge. 2012. An assessment of the final rule to implement vessel speed restrictions to reduce the threat of vessel collisions with North Atlantic right whales. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources.

Sinclair, E. H. and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). *Journal of Mammalogy* 83:973-990.

Sinclair, E. H., S. E. Moore, N. A. Friday, T. K. Zeppelin, and J. M. Waite. 2005. Do patterns of Steller sea lion (*Eumetopias jubatus*) diet, population trend and cetacean occurrence reflect oceanographic domains from the Alaska Peninsula to the central Aleutian Islands? *Fisheries Oceanography* 14:223-242.

Sinclair, E., T. R. Loughlin, and W. Pearcy. 1994. Prey selection by northern fur seals (*Callorhinus ursinus*) in the eastern Bering Sea. *Fishery Bulletin* 92:144-156.

Sohn, D. 2016. Distribution, Abundance, and Settlement of Slope-Spawning Flatfish During Early Life Stages in the Eastern Bering Sea. PhD thesis, Oregon State University, Corvallis, OR.

Somerton, D. A. and R. A. Macintosh. 1985. Reproductive biology of the female blue king crab *Paralithodes platypus* near the Pribilof Islands, Alaska *Journal of Crustacean Biology* 5:365-376.

Spear, L. B. 1993. Dynamics and effect of Western Gulls feeding in a colony of guillemots and Brandt's Cormorants. *Journal of Animal Ecology* 62:399-414.

Springer, A. M. 1991. Seabird distribution as related to food webs and the environment: Examples from the North Pacific Ocean. *Studies of High Latitude Seabirds* 1:39-48.

Springer, A. M., C. P. McRoy, and M. V. Flint. 1996. The Bering Sea Green Belt: shelf-edge processes and ecosystem production. *Fisheries Oceanography* 5:205-223.

Springer, A. M., C. P. McRoy, and K. R. Turco. 1989. The paradox of pelagic food webs in the northern Bering Sea—II: Zooplankton communities. *Continental Shelf Research* 9:359-386.

Squires, H. J. and E. G. Dawe. 2003. Stomach contents of snow crab (*Chionoecetes opilio*, Decapoda, Brachyura) from the northeast Newfoundland shelf. *Journal of the Northwest Atlantic Fishery Science* 32:27-38.

St.-Pierre, G. 1989. Recent Studies of Pacific Halibut Postlarvae in the Gulf of Alaska and Eastern Bering Sea. Scientific Report No. 73. International Pacific Halibut Commission, Seattle, WA.

Stefansson, S. O., B. T. Björnsson, L. O. E. Ebbesson, and S. D. McCormick. 2008. Smoltification, *In Fish Larval Physiology*. R. N. Finn and B. G. Kapoor eds., pp. 639-681. Science Publishers, Enfield, NH.

Stejneger, L. H. 1885. Results of Ornithological Explorations in the Commander Islands and in Kamtschatka. US Government Printing Office, Washington, DC.

Steller, G. W. 1899. The Beasts of the Sea (Translated), *In The Fur Seals and Fur-seal Islands of the North Pacific Ocean. Part 3: Special Papers Relating to the Fur Seal and to the Natural History of the Pribilof Islands*. D. S. Jordan, L. Steineger, F. A. Lucas, J. Moser, C. H. Townsend, G. A. Clark, and J. Murray eds., pp. 179-218. Government Printing Office, Washington, DC.

Stephensen, S. W. and D. B. Irons. 2003. Comparison of colonial breeding seabirds in the eastern Bering Sea and the Gulf of Alaska. *Marine Ornithology* 31:167–173.

Sterling, J. T., A. M. Springer, S. J. Iverson, S. P. Johnson, N. A. Pelland, D. S. Johnson, M. A. Lea, and N. A. Bond. 2014. The sun, moon, wind, and biological imperative–shaping contrasting wintertime migration and foraging strategies of adult male and female northern fur seals (*Callorhinus ursinus*). *PLoS ONE* 9:e93068.

Stevens, B. G. 2006a. Embryo development and morphometry in the blue king crab *Paralithodes platypus* studied by using image and cluster analysis. *Journal of Shellfish Research* 25:569-576.

Stevens, B. G. 2006b. Timing and duration of larval hatching for blue king crab *Paralithodes platypus* Brandt, 1850 held in the laboratory. *Journal of Crustacean Biology* 26:495-502.

Stevens, B. G., S. Persselin, and J. Matweyou. 2008. Survival of blue king crab *Paralithodes platypus* Brandt, 1850, larvae in cultivation: effects of diet, temperature and rearing density. *Aquaculture Research*:390-397.

Stone, R. P. 2006. Coral habitat in the Aleutian Islands of Alaska: Depth distribution, fine-scale species associations, and fisheries interactions. *Coral Reefs* 25:229-238.

Stone, R. P. 2014. The Ecology of Deep-Sea Coral and Sponge Habitats of the Central Aleutian Islands of Alaska. NOAA Professional Paper NMFS 16. National Oceanic and Atmospheric Administration, Seattle, WA.

Stone, R. P. and S. D. Cairns. 2017. Deep-sea coral taxa in the Alaska region: Depth and geographical distribution, *In The State of Deep-Sea Coral and Sponge Ecosystems of the United States: 2017. NOAA Technical Memorandum CRCP-3*. T. F. Hourigan, P. J. Etnoyer, and S. D. Cairns eds. National Oceanic and Atmospheric Administration, Silver Spring, MD.

Stone, R. P., C. E. O'Clair, and T. C. Shirley. 1992. Seasonal migration and distribution of female red king crabs in a Southeast Alaskan estuary. *Journal of Crustacean Biology* 12:546-560.

Stoner, A. W. 2009. Habitat-mediated survival of newly settled red king crab in the presence of a predatory fish: Role of habitat complexity and heterogeneity. *Journal of Experimental Marine Biology and Ecology* 382:54-60.

Stoner, A. W. and A. A. Abookire. 2002. Sediment preferences and size-specific distribution of young-of-the-year Pacific halibut in an Alaska nursery. *Journal of Fish Biology* 61:540-559.

Stoner, A. W. and M. L. Ottmar. 2004. Fish density and size alter Pacific halibut feeding: Implications for stock assessment. *Journal of Fish Biology* 64:1712-1724.

Stoner, A. W., M. L. Ottmar, and L. A. Copeman. 2010. Temperature effects on the molting, growth, and lipid composition of newly-settled red king crab. *Journal of Experimental Marine Biology and Ecology* 393:138-147.

Suryan, R. M., K. S. Dietrich, E. F. Melvin, G. R. Balogh, F. Sato, and K. Ozaki. 2007. Migratory routes of Short-tailed Albatrosses: Use of exclusive economic zones of North Pacific Rim countries and spatial overlap with commercial fisheries in Alaska. *Biological Conservation* 137:450-460.

Swennen, C. and P. Duiven. 1977. Size of food objects of three fish-eating seabird species: *Uria aalge*, *Alca torda*, and *Fratercula arctica* (Aves, Alcidae). *Netherlands Journal of Sea Research* 11:92-98.

Sydeman, W. J., J. F. Piatt, S. A. Thompson, M. García-Reyes, S. A. Hatch, M. L. Arimitsu, L. Slater, J. C. Williams, N. A. Rojek, and S. G. Zador. 2016. Puffins reveal contrasting relationships between forage fish and ocean climate in the North Pacific. *Fisheries Oceanography* 26:379-395.

Testa, J. W. 2016. Fur seal investigations, 2013-2014. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-316, 124 p.

Torrey, B. B. 1983. *Slaves of the Harvest*. TDX Corporation.

Towell, R., R. Ream, J. Bengtson, M. Williams, and J. Sterling. 2018. 2018 northern fur seal pup production and adult male counts on the Pribilof Islands, Alaska. Memorandum for the Record, November 8, 2018. Accessed 12 May 2020 from: https://www.fisheries.noaa.gov/resource/data/2018-northern-fur-seal-pup-production-and-adult-male-counts-pribilof-islands-alaska. Alaska Fisheries Science Center, Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle WA 98115.

Trites, A. W. and B. T. Porter. 2002. Attendance patterns of Steller sea lions (*Eumetopias jubatus*) and their young during winter. *Journal of Zoology* 256:547-556.

Trites, A. W., B. P. Porter, V. B. Deecke, A. P. Coombs, M. L. Marcotte, and D. A. Rosen. 2006. Insights into the timing of weaning and the attendance patterns of lactating Steller sea lions (*Eumetopias jubatus*) in Alaska during winter, spring, and summer. *Aquatic Mammals* 32:85-97.

Troy, D. M. and M. S. W. Bradstreet. 1991. Marine bird abundance and habitat use, *In Marine Birds and Mammals of the Unimak Pass Area: Abundance, Habitat Use and Vulnerability. Final Report to Mineral Management Service Contract# MMS14-35-001-30564*. pp. 5-1 to 5-70. LGL Alaska Research Associates, Inc., Anchorage, AK.

Ueda, Y., Y. Narimatsu, T. Hattori, M. Ito, D. Kitagawa, N. Tomikawa, and T. Matsuishi. 2006. Fishing efficiency estimated based on the abundance from virtual population analysis and bottom-trawl surveys of Pacific cod *Gadus macrocephalus* in the waters off the Pacific coast of northern Honshu, Japan. *Nippon Suisan Gakkaishi* 72:201-209.

US Fish and Wildlife Service. 2008. Short-tailed Albatross Recovery Plan. US Fish and Wildlife Service, Anchorage, AK.

US Fish and Wildlife Service. 2014. Pacific Walrus (*Odobenus rosmarus divergens*): Alaska Stock. US Fish & Wildlife Service, Anchorage, AK.

Van Der Hoop, J. M., M. J. Moore, S. G. Barco, T. V. Cole, P. Y. DAOUST, A. G. Henry, D. F. McAlpine, W. A. McLellan, T. Wimmer, and A. R. Solow. 2013. Assessment of management to mitigate anthropogenic effects on large whales. Conservation Biology 27:121-133.

Vanderlaan, A. S. and C. T. Taggart. 2007. Vessel collisions with whales: The probability of lethal injury based on vessel speed. Marine Mammal Science 23:144-156.

Vanderlaan, A. S., J. J. Corbett, S. L. Green, J. A. Callahan, C. Wang, R. D. Kenney, C. T. Taggart, and J. Firestone. 2009. Probability and mitigation of vessel encounters with North Atlantic right whales. Endangered Species Research.

Veltre, D.W., and M. J. Veltre. 1981. A Preliminary Baseline Study of Subsistence Resource Utilization in the Pribilof Islands, Alaska Department of Fish and Game, Division of Subsistence Technical Paper No.57. Juneau.

Veniaminov, I. and L. T. Black. 1984. *Notes on the Islands of the Unalashka District*. Volume 27. Limestone Press Kingston, Canada.

Verspoor, E., T. Birkhead, and D. N. Nettleship. 1987. Incubation and brooding shift duration in the Common Murre, *Uria aalge*. *Canadian Journal of Zoology* 65:247-252.

Wanless, S. and M. Harris. 1986. Time spent at the colony by male and female guillemots *Uria aalge* and razorbills *Alca torda*. *Bird Study* 33:168-176.

Watson, L. J. 2008. The 2007 triennial St. Matthew Island blue king crab survey and comparisons to historic surveys. Alaska Department of Fish and Game.

Wehle, D. H. S. 1976. Summer Food and Feeding Ecology of Tufted and Horned Puffins on Buldir Island, Alaska, 1975. MS thesis, University of Alaska, Fairbanks, AK.

Wehle, D. H. S. 1978. Studies of marine birds on Ugaiushak Island, *In Environmental Assessment of the Alaskan Continental Shelf. Annual Reports of Principal Investigators for the Year Ending March 1978*. pp. 208-312. National Oceanic and Atmospheric Administration, Boulder, CO.

Wehle, D. H. S. 1980. The Breeding Biology of the Puffins: Tufted Puffin (*Lunda cirrhata*), Horned Puffin (*Fratercula corniculata*), Common Puffin (*F. arctica*), and Rhinoceros Auklet (*Cerorhinca monocerata*). PhD thesis, University of Alaska, Fairbanks, AK.

Weimerskirch, H. and Y. Cherel. 1998. Feeding ecology of Short-tailed Shearwaters: Breeding in Tasmania and foraging in the Antarctic? *Marine Ecology Progress Series* 167:261-274.

Westphal, M. J., G. L. Eckert, and S. L. Tamone. 2014. Comparison of first year growth among field, hatchery- and laboratory-raised juvenile red king crab, *Paralithodes camtschaticus* (Tilesius, 1815), in Alaska. *Journal of Crustacean Biology* 34:319-325.

Whitehouse, G. A. 2013. Preliminary Mass-Balance Food Web Model of the Eastern Chukchi Sea. NOAA Technical Memorandum NMFS-AFSC-262. National Oceanic and Atmospheric Administration, Seattle, WA.

Williams, G. H. 2015. Recommendations for Pacific Halibut Discard Mortality Rates in the 2016-2018 Groundfish Fisheries Off Alaska. Report of Assessment and Research Activities 2015. International Pacific Halibut Commission, Seattle, WA.

Wilson, M. T., K. L. Mier, and D. W. Cooper. 2016. Assessment of resource selection models to predict occurrence of five juvenile flatfish species (*Pleuronectidae*) over the continental shelf in the western Gulf of Alaska. *Journal of Sea Research* 111:54-64.

Witherell, D. and C. Coon. 2002. Protecting Gorgonian corals off Alaska from fishing impacts. *In* Proceedings of the First International Symposium on Deep Sea Corals. Ecology Action Center, Halifax, Canada.

Witherell, D. and J. Armstrong. 2015. Groundfish Species Profiles. North Pacific Fisheries Management Council, Anchorage, AK.

Wong, S. N. P., C. Gjerdrum, K. H. Morgan, and M. L. Mallory. 2014. Hotspots in cold seas: The composition, distribution, and abundance of marine birds in the North American Arctic. *Journal of Geophysical Research: Oceans* 119:1691-1705.

Wright, S. K., G. V. Byrd, H. M. Renner, and A. L. Sowls. 2013. Breeding ecology of Red-faced Cormorants in the Pribilof Islands, Alaska. *Journal of Field Ornithology* 84:49-57.

Yesner, D. R. and J. S. Aigner. 1976. Comparative biomass estimates and prehistoric cultural ecology of the southwest Umnak region, Aleutian Islands. *Arctic Anthropology* 13:91-112.

York, A. E. 1983. Average age at first reproduction of the northern fur seal (*Callorhinus ursinus*). *Canadian Journal of Fisheries and Aquatic Sciences* 40:121-127.

York, A. E. and V. B. Scheffer. 1997. Timing of implantation in the northern fur seal, *Callorhinus ursinus*. *Journal of Mammalogy* 78:675-683

Young, R. C., A. S. Kitaysky, C. Carothers, and I. Dorresteijn. 2014. Seabirds as a subsistence and cultural resource in two remote Alaskan communities. *Ecology and Society* 19.

Zeppelin, T., Pelland, N., Sterling, J., Brost, B., Melin, S., Johnson, D., Lea, M.-A., & Ream, R. 2019. Migratory strategies of juvenile northern fur seals (*Callorhinus ursinus*): bridging the gap between pups and adults. Scientific Reports, 9(1), 1. https://doi.org/10.1038/s41598-019-50230-z

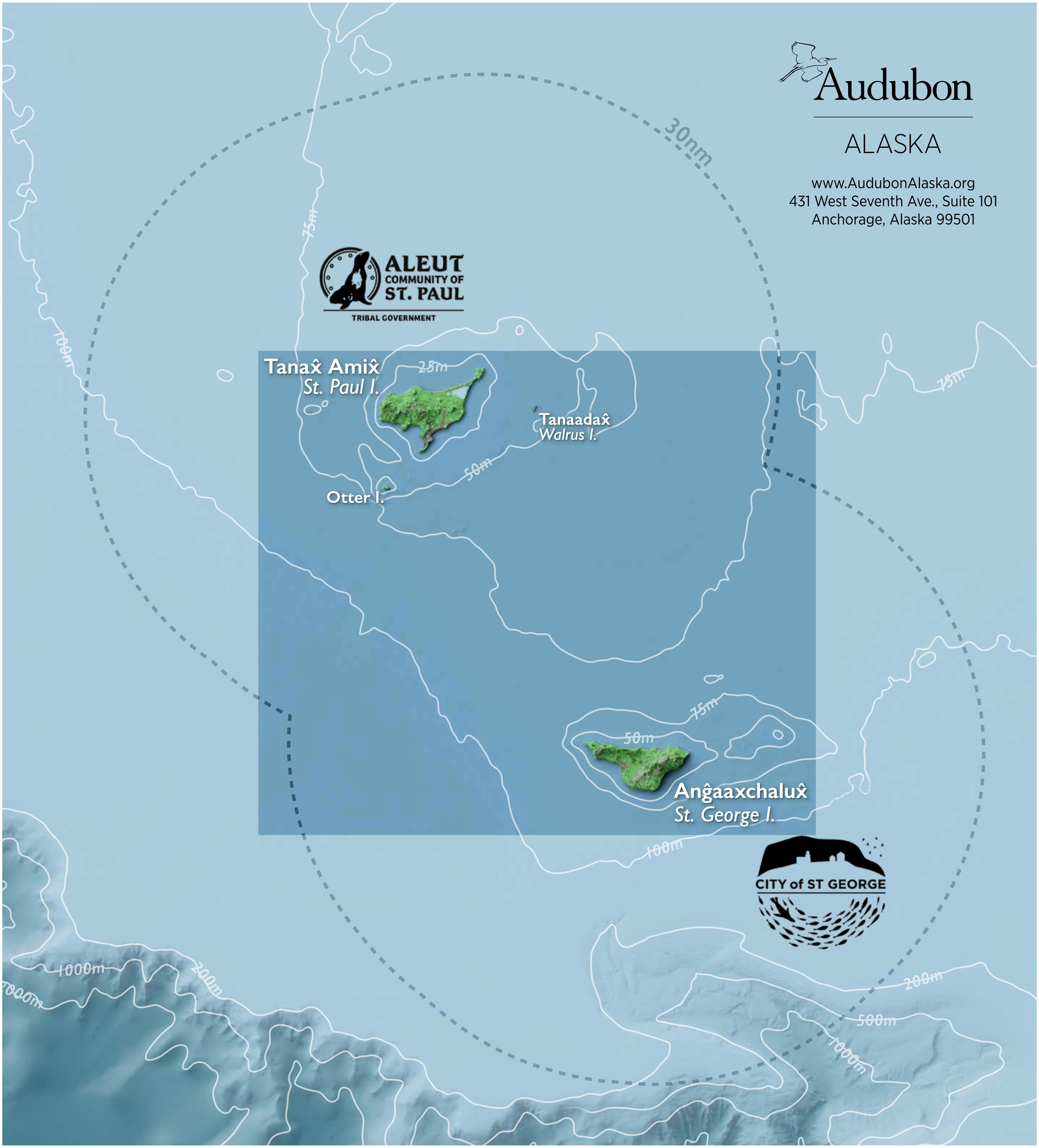
Zeppelin, T. K., & Ream, R. R. (2006). Foraging habitats based on the diet of female northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Alaska. Journal of Zoology, 270(4), 565–576. https://doi.org/10.1111/j.1469-7998.2006.00122.x

Zheng, J. and G. H. Kruse. 2006. Recruitment variation of eastern Bering Sea crabs: Climate-forcing or top-down effects? *Progress in Oceanography* 68:184-204.

Zheng, J., S. Siddeek, D. Pengilly, and D. Woodby. 2002. Overview of Recommended Harvest Strategy for Snow Crabs in the Eastern Bering Sea. Regional Information Report No. 5J02-03. Alaska Department of Fish and Game, Juneau, AK.

Zimmermann, M. and Prescott, M. 2018. Bathymetry and Canyons of the Eastern Bering Sea Slope. Geosciences, 8(5), 184. https://doi.org/10.3390/geosciences8050184


R. Mong


Audubon
ALASKA
www.AudubonAlaska.org
431 West Seventh Ave., Suite 101
Anchorage, Alaska 99501
ALEUT COMMUNITY OF ST. PAUL
TRIBAL GOVERNMENT
30nm
Tanax̂ Amix̂
St. Paul I.
Tanaadax̂
Walrus I.
Otter I.
Angâaxchalux̂
St. George I.
CITY of ST GEORGE
25m
50m
75m
100m
200m
500m
1000m
2000m