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Short communication

First results of the tagging of shortspine thornyhead, *Sebastolobus alascanus*, in Alaska

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ABSTRACT

Shortspine thornyhead (*Sebastolobus alascanus*) is a commercially valuable deep dwelling rockfish species that has been tagged in Alaska waters since 1992. These tagging results are the primary analyses available for evaluating the movement of this species, which will allow managers to determine the appropriate geographic scale of management. A total of 13,897 tagged fish have been released, with 228 recoveries reported during 1992–2016. Of the returned tags, 19% traveled < 2 M (nm) between tagging and recovery location, 36% traveled 2–5 nm, 18% traveled 6–10 nm, 12% traveled 11–50 nm, 4% traveled 51–100 nm, and 11% traveled > 100 nm. While a small percentage of tagged shortspine thornyhead traveled large distances, at times crossing management and international boundaries, the low movement rate indicates that the current scale of management for shortspine thornyhead rockfish in Alaska appears to be appropriate.

1. Introduction

Shortspine thornyhead (*Sebastolobus alascanus*, SST) is a long-lived, commercially valuable, deep dwelling species that inhabits the northeastern Pacific Ocean from Baja Mexico to the Gulf of Alaska (GOA), westward to the Aleutian Islands (AI), Eastern Bering Sea (BS), and into the Seas of Okhotsk and Japan (Love et al., 2002). Adult SST are generally found along the continental slope at depths of 150–450 m. Thornyheads belong to the family Scorpanenidae, which contains the rockfishes. While SST are considered rockfish, they are differentiated from *Sebastes* in that they lack a swim bladder, making them ideal tagging specimens. The Alaska Fisheries Science Center (AFSC) of the National Marine Fisheries Service (NMFS) has been tagging SST in Alaska waters since 1992. To our knowledge this is the first tagging study on this species. We present here the first summary of the release and recapture data from SST tagging.

Spatially explicit management, that is managing allowable catch by areas, is used for management of several economically important fisheries in Alaska, including the thornyhead stock complex fishery. The thornyhead complex contains three *Sebastolobus* species, including SST (Echave et al., 2015). To help managers determine the appropriate scale of spatial management, an understanding of the distribution and movement of fishes is necessary. Tagging of SST occurs during stock assessment surveys. Analysis of tag data is used to examine SST movement patterns and can assist with questions regarding stock structure and growth. The objectives of this study are to provide a summary of the information on SST growth and movement based on these tagging data, and to examine how these growth and movement results contribute to the definition of SST stock structure.

2. Material and methods

Tagging of SST first occurred in 1992, but was inconsistently done until 1997. Since then SST have been tagged in offshore waters as part of the NMFS annual Alaska Fisheries Science Center Longline Survey (Rutecki et al., 2016). The AFSC longline survey is primarily used for the assessment of sablefish (*Anoplopoma fimbria*), but catches other species of interest as well, such as the shortspine thornyhead. Fig. 1 shows the major release and recovery areas, as well as the location of the annual longline survey stations. Approximately 5% of the longline survey catch of SST was tagged and released each year, which generally equals about 500–1000 fish per year (Table 1). Most of the tagged and released fish carried conventional anchor tags, whereas a small portion also carried internally implanted electronic archival tags. Conventional anchor tags (www.floytag.com) are 1.5 inches long, and inserted externally into the musculature of the fish below the dorsal fin using a needle-like applicator (Fig. 2). Upon recapture of conventionally tagged fish, geo-location and biological data may be collected. Electronic archival tags (www.Lotek.com) are electronic data collecting tags that are surgically implanted into the abdomen of the fish (Fig. 3). These archival tags collect temperature and depth data at a predefined sampling rate. Fish tagged with electronic archival tags were also tagged with a fluorescent pink and green external tag stating that an "Electronic depth sensor" was inside the fish. Upon recapture of the archival tagged fish,

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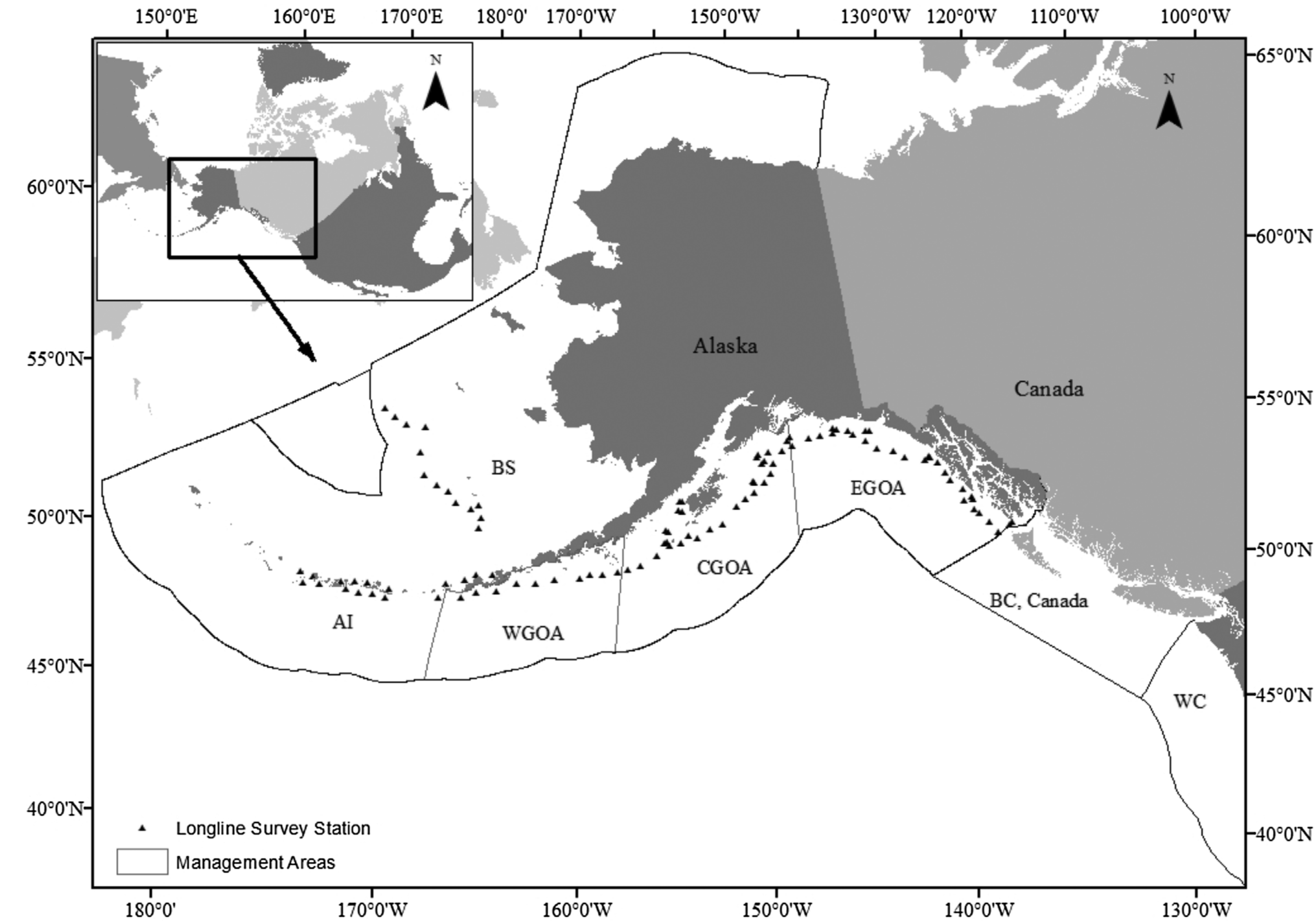

Fig. 1. Map depicting the NMFS annual longline survey stations (triangles) and management areas: the Bering Sea (BS), Aleutian Islands (AI), Western Gulf of Alaska (WGOA), Central Gulf of Alaska (CGOA), and Eastern Gulf of Alaska (EGOA). Tags are deployed at all stations in the GOA each year, and in alternating years in the BS and AI. Additionally, British Columbia (BC), Canada and West Coast of the United States (WC) are noted.

data that are collected include the release and recovery location, archived depth and temperature data, and biological data (e.g., otoliths, length/weight at release and recapture). Because archival tagged fish include similar data (release location, recovery location, and growth), their release and recovery data are pooled with conventional tag release and recovery data and presented together throughout the paper. All SST tag recoveries have occurred during commercial fishery activities and fishery-independent surveys. Analysis of data from recovered archival tags is still underway and will be presented in a separate paper.

All tag recoveries are given a position accuracy score of 1–5: 1 means position is precise to at least the nearest minute of latitude and longitude (0.5–1 nautical mile, nm), 2 means position is precise to the nearest 10 min of latitude and longitude (5–10 nm), 3 means position is precise to the nearest degree of latitude and longitude and includes most Alaska Department of Fish and Game statistical areas (30–60 nm), 4 means position is precise to the nearest 3 ° (90–180 nm) and also includes recoveries where only general area is known such as Eastern Gulf of Alaska, and 5 means position is completely unknown. The release location recorded in the tag database for all tag releases from the longline survey are the start coordinates for the station haul. However, each haul is approximately 4 nm in length and fish that are tagged from the longline survey aren't released at their exact catch location, but generally further along the set of gear.

3. Results

Since 1992, 13,897 SST have been tagged and a total of 228 tagged SST have been recovered (Table 1). The majority of recovered tags have been caught using commercial longline gear (160 tags). Fifty of the 228 total recovered tags have been caught on the NMFS annual AFSC Longline Survey. The majority of tag recoveries have been from the Central (75 tags) and Eastern (83 tags) GOA (Table 2). The shortest duration a tag was at liberty was for 2 days, and the longest was 15.5 years. The fish at liberty for 15.5 years grew 10 mm in that time and was recovered only 4.3 nm from the release location. The fish at liberty for 2 days "traveled" 7.8 nm. The average time at liberty for all recovered SST tags was just under 4 years.

Using only recoveries with a position accuracy code of 1, the great circle distance traveled by a tagged SST ranges from $<$ 1 nm to 990 nm. Of these, 19% traveled $<$ 2 nm, 36% traveled 2–5 nm, 18% traveled 6 − 10 nm, 12% traveled 11–50 nm, 4% traveled 51–100 nm, and 11% traveled $>$ 100 nm. The average distance traveled was 46 nm, with no apparent difference in travel distance by sex (male = 49 nm and female = 44 nm; two sample *t*-test (96) = 0.03, p = 0.49; Table 3). It is important to note that movement of less than 5 nm could be influenced by the survey haul coordinates that are used as the tag release location, as mentioned in the Methods section. The elapsed time between capture and release varies and this could affect the distance between release and recapture estimates.

Apparent movement patterns appear to be unrelated to fish size at release based on a one-way ANOVA (F(2, 168) = 0.48, p = 0.6). The average distance traveled was greatest (95 nm) for the largest size group ($>$ 40 cm), but a fish from the smallest size group ($<$ 33 cm) traveled the farthest maximum distance (990 nm; Table 3). Note that

Table 1
Total number of conventional and archival tagged shortspine thornyhead released each year, total number of conventional and archival tags subsequently recovered from each year's release, and total number of tags recovered each year regardless of their year of release.

Year	Number of Conventional Tags Released Each Year	Number of Archival Tags Released Each Year	Number of Conventional Tags Subsequently Recovered	Number of Archival Tags Subsequently Recovered	Total Number of Tags Recovered Each Year
1992	100	–	–	–	–
1997	495	–	17	–	–
1998	525	–	22	–	3
1999	618	–	22	–	5
2000	501	–	12	–	7
2001	637	–	9	–	9
2002	586	–	19	–	10
2003	532	56	18	1	8
2004	420	53	12	–	10
2005	556	–	7	–	12
2006	549	94	7	–	11
2007	681	–	8	–	11
2008	607	–	15	–	12
2009	783	–	11	–	16
2010	947	–	10	–	23
2011	912	–	11	–	14
2012	748	–	15	–	11
2013	1123	–	8	–	19
2014	738	–	–	–	28
2015	870	–	4	–	15
2016	766	–	–	–	3

these are arbitrary size breaks based on the amount of available data and not for biological reasons.

While the majority of tagged SST showed little to no movement (i.e., 73% of tagged recoveries traveled less than 10 nm), there have been some long-distance movements, and some fish crossed management and international boundaries. Fig. 4 shows the release and recovery locations of all tagged recoveries that displayed total movement > 50 nm. This figure highlights the inclination for a SST to move in an east/southeast direction. Of particular interest are the number of recoveries in British Columbia (BC), Canada (Fig. 5), and the concentrated area of these recoveries near Haida Gwaii (formerly known as the Queen Charlotte Islands). The majority of recovered SST, however, remained within their management area of release (Table 4). Shortspine thornyhead that were tagged and released in the Eastern GOA were more inclined to be recaptured than SST tagged in any other area (Fig. 5). Of the 102 recoveries that were released in the Eastern GOA, 76% remained within the Eastern GOA, 18% were recovered in BC, 5% were recovered in the Central GOA, and 1% were recovered on the U.S. West Coast (WC). These numbers include all recoveries from Eastern GOA tag releases with a position accuracy score of 1–4.

Nearly half (48%) of the 153 fish with reliable size information showed no change in length (39 fish) or a decrease in length (35 fish). It appears that larger fish are more prone to shrinking; 34 of the 35 fish that shrank were > 33 cm, and the largest decreases (> 10 cm) in

Fig. 3. Figure of an electronic archival tag (www.Lotek.com) to be surgically implanted into the abdomen of a shortspine thornyhead.

Table 2
Total number of tagged shortspine thornyhead released by area, subsequently recovered from each area's total releases, and recovered by area regardless of release area. Eastern Bering Sea (BS), Aleutian Islands (AI), Western Gulf of Alaska (WGOA), Central Gulf of Alaska (CGOA), Eastern Gulf of Alaska (EGOA), British Columbia (BC), and U.S. West Coast (WC). Tags with position accuracy code of 1–4 are included. Total recovered by area will not add up to the actual total number of tags recovered, due to no recovery location data on 14 tags (i.e., position accuracy code = 5).

Area	Total Released by Area	Total Subsequently Recovered from each Area's Releases	Total Recovered by Area
BS	664	4	16
AI	695	15	3
WGOA	1747	16	16
CGOA	4536	86	75
EGOA	6255	107	83
BC	–	–	20
WC	–	–	1

Table 3
Minimum (min), maximum (max), and average (avg) distance traveled (great circle distance; nautical miles) by sex, and size (cm). Sex 1 = male, sex 2 = female, and sex 3 = unknown. Results by size include all sexes pooled. Only fish with position accuracy code of 1 are included in this summary.

Sex	Min Distance	Max Distance	Avg Distance
1	0.7	594	49
2	0.3	503	44
3	0.6	990	43
Size (cm)			
< 33	0.3	990	45
33 – 40	0.6	595	49
> 40	0.7	750	95

length were by fish > 40 cm. Additionally, nearly a quarter (23%) of the fish exhibiting a decrease in length were recovered in BC. The phenomena has been observed in tagged fish recovered by NMFS research vessels and by scientific observers. Ten of the 89 tagged SST recovered on NMFS research vessels or by observers showed a decrease in size.

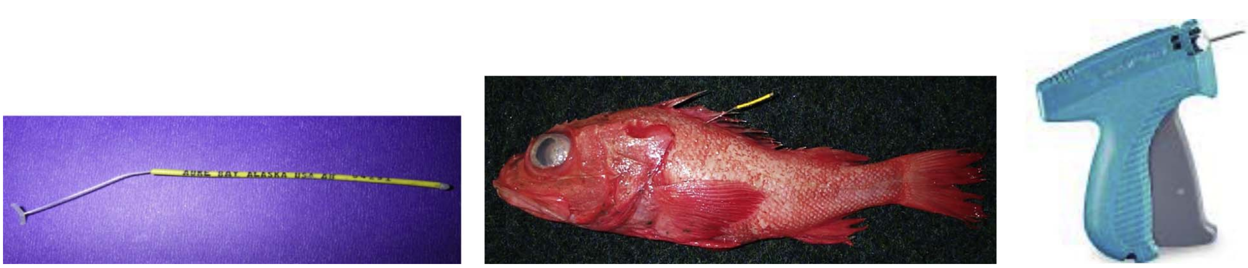

Fig. 2. Figures of a conventional tag (on left; www.floytag.com), tag inserted into a shortspine thornyhead (middle), and needle like tag applicator used to insert the tags. Tag is inserted slightly below the dorsal fin.

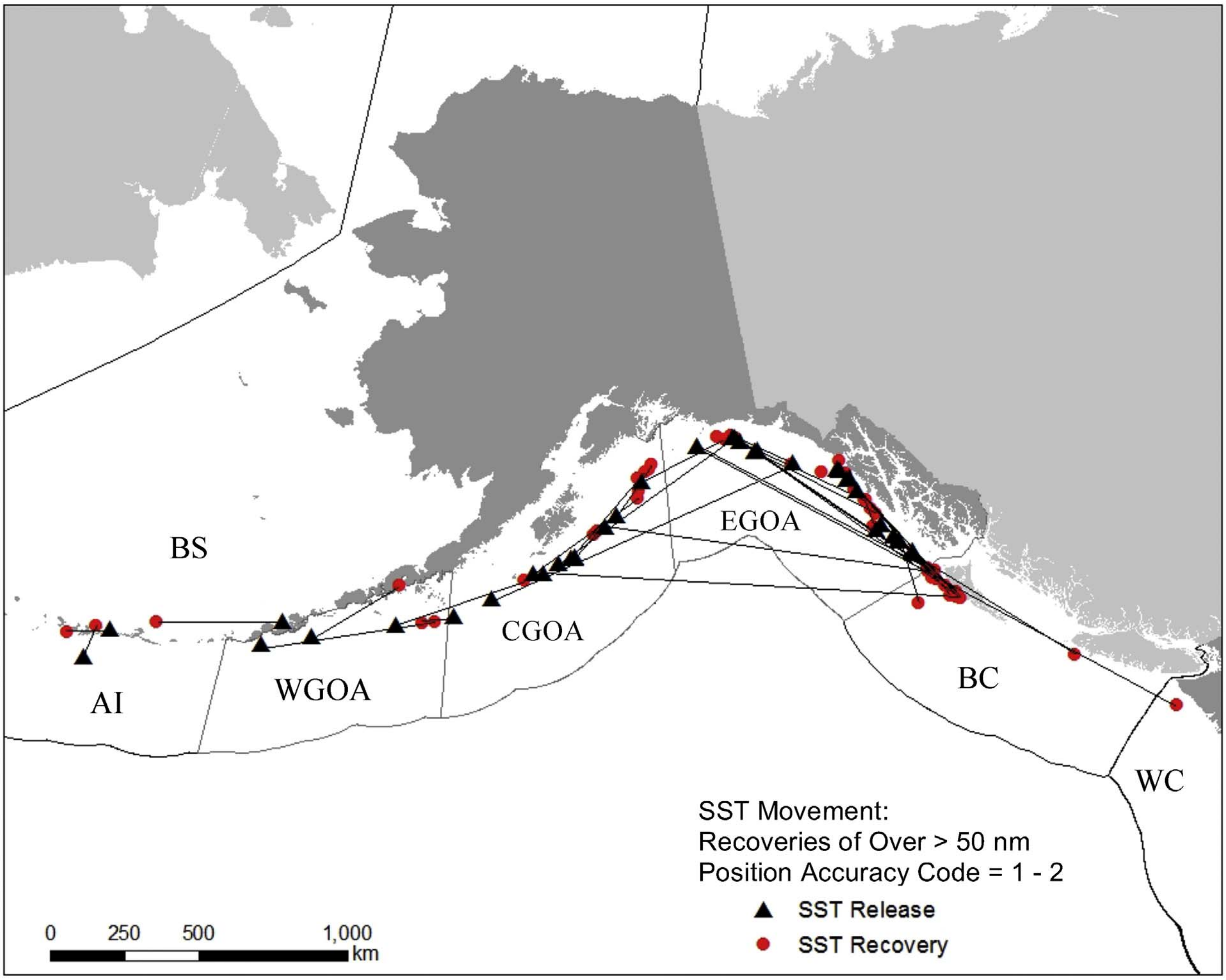

Fig. 4. Figure displaying movement of tagged shortspine thornyhead that traveled over 50 M (nm) between their release (black triangle) and recovery (red dot) locations. Line represents great circle distance between the release and recovery locations, and is not representative of the path traveled between the two points. Data with position accuracy code of 1–2 are displayed. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

Shortspine thornyhead are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan. Although the thornyhead fishery in Alaska is managed operationally as a "by-catch" fishery, the high value and desirability of SST means they are still considered a "target" species for the purposes of management. SST are managed as a single stock in the GOA (Ianelli and Ito, 1995; Ianelli et al., 1997), but the Allowable Biological Catch (ABC) and Total Allowable Catch (TAC) are currently apportioned, using NMFS trawl survey biomass estimates, into three geographic management areas: the Western, Central, and Eastern Gulf of Alaska (Echave et al., 2015). For this reason, an understanding of the spatial distribution and movement of SST is necessary to help managers determine if the current scale of management is appropriate, and to estimate movement rates among management areas. The results of this paper show that a small percentage of tagged SST traveled large distances, at times crossing management boundaries.

The collection of biological data (e.g., length, weight, and age) during the release and recapture of a tagged fish, especially from a study covering such broad geographic areas as the GOA and Eastern BS, can help determine if geographical differences in growth exist. Unfortunately, the small sample size of recovered tags with reliable growth data, in addition to the current inability to reliably age SST, have complicated growth analyses. New questions have been raised over how SST in some cases appear to be shrinking. Zero growth fish ranged in time at liberty between 33 days and almost 14 years, consistent with reports that SST are slow growing (Love et al., 2002). Recovered tags come from a number of sources (fishermen, processors, scientists, and scientific observers), so it is expected that some data, such as length measurements, may vary due to measurement error. This is especially true on a slow growing species such as SST, where the accuracy of a measurement to the cm in fork length can be difficult, but can make a large difference if inaccurate in one direction. Observation error is expected and can be accounted for in scientific studies. However, the number of recovered fish with decreases in length, especially fish that were recaptured and measured by scientists during scientific cruises, was notable.

The amount of movement by SST varied by tagging location, as did the direction of movement. However, there was no significant difference in movement by fish size. All fish included in this analysis are > 27 cm, and are therefore likely mature (Pearson and Gunderson 2003). The majority of SST that move generally traveled east/southeast, and fish that were tagged and released in the Eastern GOA were more inclined to move than fish from other areas. These regional differences in recapture patterns may highlight an actual propensity for movement from the Eastern GOA, or reflect geographic differences in fishing effort, particularly at depth. The number of recoveries in BC, Canada, with the concentrations of recoveries near Haida Gwaii, could be related to greater fishing effort there (e.g., trawlers that fish deeper targeting sablefish and dover sole). Overall, the majority of recovered SST remained within their management area of release, and very near their

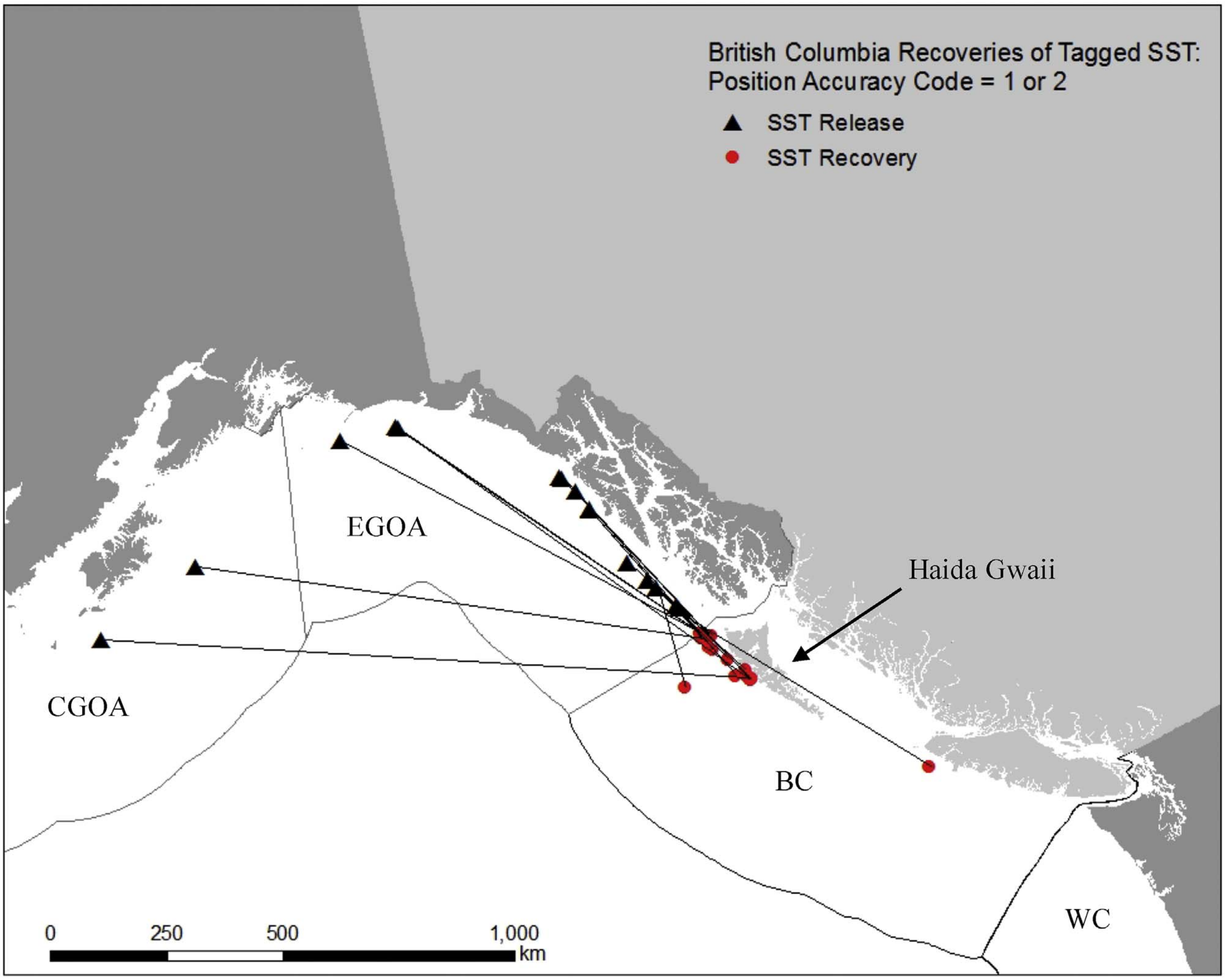

Fig. 5. Figure displaying movement of tagged shortspine thornyhead that were recovered in British Columbia (BC). The line represents great circle distance between the release (black triangle) and recovery (red dot) locations, and is not representative of the path traveled between the two points. Data with position accuracy code of 1 or 2 are presented. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

actual release location. While the relatively small number of recovered tags makes estimating movement rates difficult, the existing recoveries suggest low movement rates. When defining the stock structure of SST in Alaska waters, one may conclude that this species displays little movement, but that large movements are possible.

Several research questions remain unanswered due to the small number of tag recoveries. For example, it is unknown what tag reporting rates for SST are and whether they differ by gear and/or area of recovery. Tag reporting rates for SST are likely smaller than those for other species (e.g., sablefish; Heifetz and Maloney 2001; Echave et al., 2013) for many reasons, one being that the yellow tags are harder to see next to the orange coloring of these fish. The high discrepancy of recoveries by fishery gear type is also notable, and likely a result of the nature of these different fisheries. Many fish caught on longline gear are visually inspected at the roller and/or processed on the vessel, and a tag on a fish is more easily detected. Fish caught on trawl gear are generally dropped on deck and sorted into holding tanks until delivery to a plant. The amount of visual inspection on a trawl vessel is minimal. Recovered tagged fish caught on trawl vessels have generally been turned in by workers at the processing plant following delivery. As more vessels are required to have onboard observers, the number of tag recoveries will likely increase. Tag loss rates and tagging mortality are also unknown and require further examination.

The determination of the stock structure of all federally managed

Table 4
The percentage and actual number in parentheses of tagged fish from each release area (left hand row headers) that were recovered in each recovery area (top column headers). Fish with position accuracy code of 1 − 4 are included in this analysis. Total recoveries will not add up to the actual total number of tags recovered, due to no recovery location data on 14 tags (i.e., position accuracy code = 5).

	Recovery Area						
Release Area	AI	EBS	WGOA	CGOA	EGOA	BC	WC
AI	75% (3)	25% (1)					
EBS		100% (15)					
WGOA			94% (15)	6% (1)			
CGOA			1% (1)	90% (69)	7% (5)	3% (2)	
EGOA				5% (5)	76% (78)	18% (18)	1% (1)

fish stocks in Alaska is mandated by the North Pacific Fishery Management Council. This practice is used to determine if the current spatial scale of management is appropriate for each respective stock. Having the wrong spatial scale of management could lead to localized depletion if fishery effort is not appropriately distributed in relation to abundance, especially on a fish stock that shows little to no movement. Specific factors and criterion used to define a stock structure include, but are not limited to: harvest and trends, barriers and phenotypic characters, behavior and movement, and genetics. Tagging studies can assist in informing several of these criteria, as we have already noted, but genetic studies are especially useful when a species is unable to be tagged or if the number of recoveries is too few to provide accurate results. Genetic variation using tDNA was analyzed for SST from seven sites off the North American west coast, including one Alaska site off Seward (Central GOA; Stepien et al., 2000). Significant population structure was found in that study that was previously undetected with allozymes (Siebenaller, 1978). Gene flow was substantial among some locations and diverged significantly in other locations. Significant genetic differences among some sampling sites for SST indicated barriers to gene flow, and genetic divergences among sampling sites indicated an isolation-by-geographic-distance pattern. Differences in geographic genetic patterns are attributed to movement patterns as juveniles and adults. While the number of SST tag recoveries to date has been too small to fully analyze the effect that this may have on harvest allocations, the low movement rate indicated in this document, coupled with an isolation-by-geographic-distance pattern (Siebenaller, 1978), indicate that the current scale of management of using at least sub-areas in Alaska is appropriate.

5. Conclusions

Tagging of SST is planned to continue on the AFSC annual Longline Survey in Alaska. As more tags are recovered and additional tag studies implemented, potential research questions such as estimating tag loss, movement rates, and reporting rates will be investigated. In addition, data has yet to be retrieved off of the recovered electronic tag, which may provide insight into the vertical movements and different behaviors of this species. This paper is the first to report that SST are capable of traveling large distances. Further research with archival tags and accounting for relative effort and gear distributions across regions will illuminate these observations.

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