Preliminary Life History Variability of Longnose Skate (*Raja rhina*) Across Two Large Marine Ecosystems: Gulf of Alaska and California Current System

Christopher Gburski
Alaska Fisheries Science Center,
National Marine Fisheries Service, NOAA, Seattle, WA

Thomas Helser
Alaska Fisheries Science Center,
National Marine Fisheries Service, NOAA, Seattle, WA

Vladlena Gertseva
Northwest Fisheries Science Center,
National Marine Fisheries Service, NOAA, Seattle, WA

Jacquelynne King
Pacific Biological Station
Department of Fisheries and Oceans, Nanaimo, BC

David Ebert
Pacific Shark Research Center
Moss Landing Marine Laboratories, Monterey, CA

Abstract

The longnose skate, *Raja rhina*, is common in the eastern North Pacific Ocean ranging from the Bering Sea to Baja California and occurs from close inshore to a maximum of 1000 m depth. In the Gulf of Alaska (GOA), it has a maximum total length of 145 cm. A directed fishery for Raja spp off Kodiak Island, Alaska was initiated in 2003, ending in 2005. An experimental fishery in Prince William Sound, Alaska was reinstated in 2009. The vulnerability of elasmobranchs to over exploitation from commercial fishing, either from bycatch or a directed fishery, is well- documented. This inter-agency and institutional (AFSC, NWFSC, PBS/DFO and PSRC/MLML) collaborative study quantitatively compares growth and age/size at sexual maturity of the longnose skate across two large marine ecosystems, the GOA and California Current Ecosystem (CCE), on a spatial and temporal scale. Potential environmental (e.g., bottom water temperature) and oceanographic influences on life history traits between the GOA and CCE are also examined. Vertebrae (n=838) for this study were collected off the GOA, British Columbia (BC) and U.S. west coast states between 2001 and 2009 from research surveys and via port sampling. Ages were estimated, with a maximum age of 26 years, from vertebrae prepared with the standard (unstained) thin sectioning technique in this preliminary study. A new histological (stained) method will be applied to archival vertebrae in the future. Age estimates from the standard technique and a new histological method will be compared to validated ages from a longnose skate ^{14}C study. The methods estimated ages that best fit the validated ages will be used to standardize ageing criteria among agencies therefore optimizing age determination for use in stock assessment and management.

Study objective

Preliminarily estimate age, growth, and maturity parameters of longnose skates in the GOA and CCE. Generate hypothesis as to how life history parameters vary across large marine ecosystems. Provide an explanation as to what mechanisms might be responsible for the observed patterns.

Materials and methods

Specimen Collection

GOA -AFSC

n = 211 (115 males and 96 females) were collected from May 18–July 31, 2009 on the NMFS bottom trawl survey conducted by the RACE division in the GOA from 54º 30´ N latitude to 170º W longitude (Fig. 1)

BC-PBS

n = 226 (101 males and 73 females) collected from May 31–June 5, 2001; June 10–28, 2002; May 22–June 7, 2003 on groundfish bottom trawl surveys and from April 27–May 25, 2004 on shrimp trawl research surveys off the west coast of Canada (Fig. 1)

WC-NWFSC[1]

n = 401 (176 males and 225 females) collected from July 10–August 15, 2003 from Coos Bay, Oregon to the US/Mexico border, and from August 30–September 15, 2003 from Cape Flattery, Washington to Astoria, Oregon on the NOAA Fisheries West Coast groundfish survey. Additional skates were collected monthly in 2003 on commercial groundfish trawl landings in Newport, Oregon (Fig. 1)

Thoracic vertebrae were excised; skates were sexed, scanned or reproductive organs measured for sexual maturity (Fig. 2) and measured for total length (±1 mm) at sea

Vertebra preparation and ageing precision

- Vertebrae were sectioned (≈0.3 to 1.5 mm thick) on the longitudinal plane either with a low- or hi- speed saw and microscope slide mounted (Fig. 3a)
- Growth bands from unstained vertebrae were examined under a dissecting microscope with reflected or transmitted light with the addition of mineral oil for band enhancement
- Opaque and translucent band pairs were interpreted as an annulus, 1 year of growth, from the corpus calcareum and intermedialia (Fig. 3b)
- Ten vertebrae collected in the GOA were prepared with a histological staining (hematoxylin) technique[2 and 3] during a pilot study (Fig. 3b)
- Band counts were made independently by up to 3 age readers for each randomly selected specimen and age discrepancies were resolved (Table 1)

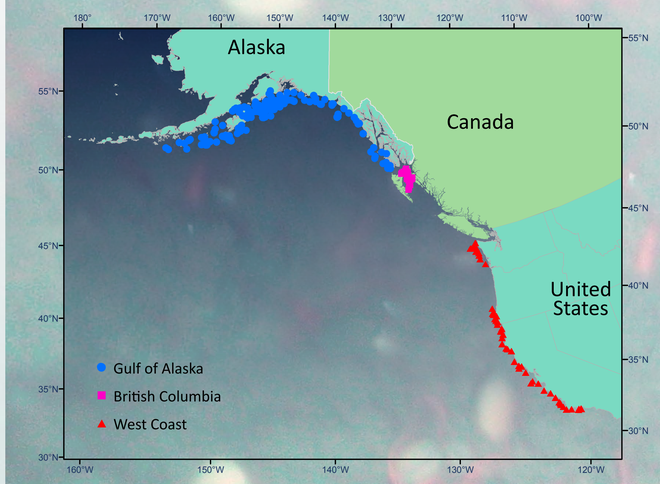


Figure 1 Longnose skate collection areas. GOA, BC and WC.

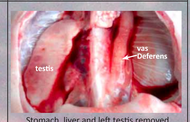
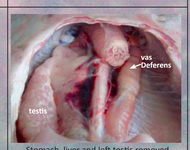
Table 1 Reader-tester precision for GOA, BC and WC, sexes combined

Region	*n*	% tested	Agreement (%) ± 0	CV	APE
GOA	54	24.4	35.2	8.2	5.8
BC	39	22.4	4.0	5.7	0.04
WC	100	20.0	28.4	13.8	8.3

Table 2 A comparison of longnose skate sampling data, age and von Bertalanffy growth parameters by region. Numbers in brackets are 95% confidence intervals for parameter estimates

Region	Sex	n	TL (mm) Range (mm)	Max Age (year)	L_{inf} (mm TL)	K	t_0(year)	r^2
GOA	♂	115	210-1420	23	1649.6 [1298.6-2000.6]	0.068 [0.037-0.098]	-1.72 [-3.068-(-0.376)]	0.797
GOA	♀	96	340-1440	22	2384.6 [993.2-3776]	0.039 [0.0001-0.077]	-2.48 [-5.621-0.655]	0.742
GOA	♂ / ♀	211	210-1440	23	1943.5 [1501.4-2385.6]	0.052 [0.030-0.075]	-1.98 [-3.298-(-0.660)]	0.776
BC	♂	101	186-1220	23	1311.6 [1076.9-1546.4]	0.069 [0.041-0.097]	-2.09 [-3.405-(-0.775)]	0.871
BC	♀	73	184-1246	26	1371.8 [1132.0-1611.6]	0.064 [0.040-0.088]	-1.80 [-2.993-(-0.616)]	0.905
BC	♂ / ♀	174	184-1246	26	1337.9	0.067	-1.92	0.888
WC	♂	175	190-1290	20	[1177.2-1498.6] 11770.6	[0.049-0.085] 0.005	[-2.776-(-1.072] -4.62	0.891
WC	♀	225	180-1420	22	[-34436.9-57978.1] 2292.9 [1544-3042]	[-0.015-0.025] 0.034 [0.018-0.050]	[-6.182-(-3.050)] -2.97 [-3.833-(-2.112)]	0.903
WC	♂ / ♀	400	180-1420	22	3203.0 [1734.9-4671.1]	0.021 [0.009-0.034]	-3.62 [-4.405-(-2.840]	0.987

(a)*

stage	characteristics	internal morphology
1 juvenile (immature)	• Testes small, undeveloped • Claspers do not extend beyond posterior edge of pelvic fin • No coiling of vas Deferens • No altar thorns on wings	Stomach, liver and left testis removed
2 adolescent (maturing)	• Testes developing • Claspers extend beyond posterior edge of pelvic fin, but are still flexible • Some coiling of vas Deferens • Altar thorns may be present on wings	 Stomach, liver and left testis removed
3 adult (mature)	• Testes are large and completely differentiated, small lobes present over surface • Claspers are hard and elongated • Highly coiled vas Deferens • Altar thorns are present on wings	 Stomach, liver and left testis removed
4 none for males	no stage 4 for males	no stage 4 for males

(b)*

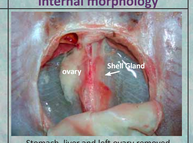
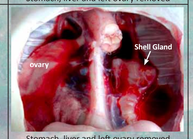
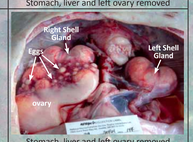
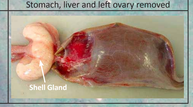
stage	characteristics	internal morphology
1 juvenile (immature)	• Ovaries small, undeveloped • Shell gland small, appears as a thickened part of the oviduct	 Stomach, liver and left ovary removed
2 adolescent (maturing)	• Ovaries developing • Eggs are noticeable and white (unyolked) • Shell gland is widening but still translucent and somewhat soft	 Stomach, liver and left ovary removed
3 adult (mature)	• Ovaries large with multiple eggs • Eggs are large and yellow (yolked) • Shell gland is large, opaque, lima bean shaped	 Stomach, liver and left ovary removed
4 adult (mature)	• Egg cases fully formed or starting to form from shell gland	

Figure 2 GOA skate (a) male and (b) female maturity stages (example).
*Skate maturity tables courtesy of Beth Matta and Olav Ormseth

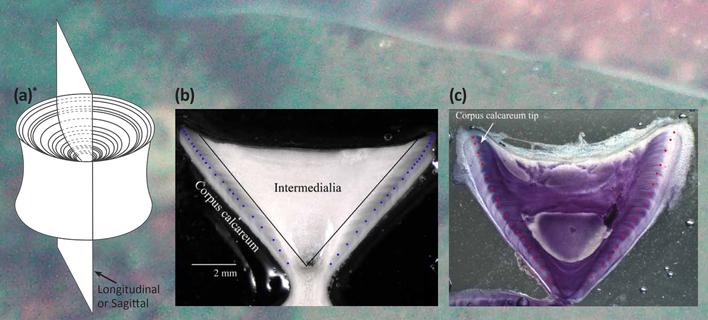


Fig. 3 (a) Vertebral thin section cutting axis. (b) Longnose skate vertebral thin section prepared using the standard (unstained) method used for this study, aged at 22 years. (c) Longnose skate histological (stained) vertebral thin section from the pilot study
*Illustration adapted by Wendy Carlson (AFSC Graphics Unit)[4]

Results

- The reader-tester percent agreement from all regions ages varies from 4.0 % to 35.2 % (Table 1)
- The percent agreement from the pilot study tested stained specimens (*n* = 13) was 23.1 %
- The length range for aged specimens and maximum age are similar across all regions. The L_{inf} values for males, females and sexes combined vary considerably across all regions (Table 2)
- The GOA male and female length distributions are skewed towards the greater lengths (> 1000 mm TL) while compared to BC and WC. Male and female length distributions for BC and WC are similar even with the WC sample size (*n*= 401) more than double that of GOA and BC. Overall, the male and female von Bertalanffy growth curves show a greater length-at-age for GOA while compared to BC and WC (Fig. 4). The GOA and WC male growth curves converge at an age of 19 years and length of 1200 mm (Fig. 4b)
- Females from the GOA and BC mature at a younger age than WC. For GOA and BC, females reach 50.0% sexual maturity at 11 years and at 17 years for WC (Fig. 5)

Conclusions

- Overall, L_{inf} values are variable although male and female L_{inf} are similar for BC
- Maximum ages between both ecosystems (GOA and CCE) and among all three geographic regions (GOA, BC and WC) appear reasonably consistent
- Length ranges from aged skates from all regions are similar even with an almost doubling of sampled skates from the WC
- The average total length-at-age is highest from the GOA and lowest from BC (sexes combined). Inter-agency age interpretation may explain these age differences
- Differences in maturity characteristics, maturing or fully mature, and maturity stage assignment may explain the disparity while comparing GOA and BC to WC

Future research

- Reevaluate ageing criteria upon completion of initiated ^{14}C bomb derived age validation study for longnose skates
- Synchronize ageing criteria with inter-agency age comparison of stained and unstained vertebrae
- Age current specimens to expand sample sizes for all regions and reevaluate growth parameters
- Investigate regional differences in maturation and onset of maturity
- Explore environmental (e.g., bottom water temperature), oceanographic effects and potential influences on life history traits across the GOA and CCE ecosystems; including the 'current break' between the Alaska and California Current

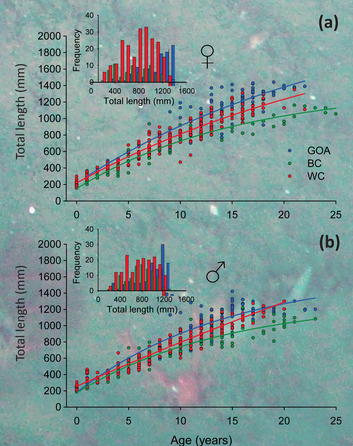


Fig. 4 Average total length-at-age (von Bertalanffy growth curves) and frequency histograms from (a) females and (b) males; GOA (96 females, 115 males, BC (73 females, 101 males), WC (225 females, 176 males)

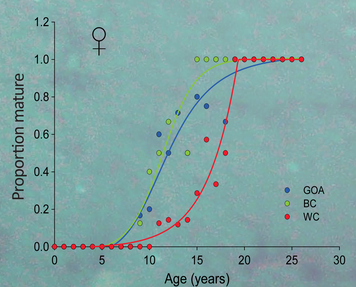


Fig. 5 Age at proportion mature (logistic curves) for females; GOA (n = 96), BC (n = 73) and WC (n = 225)

[1]Thompson, J.E. 2006. Age, growth and maturity of the longnose skate (Raja rhina) on the US West coast and sensitivity to fishing impacts. Unpublished MS Thesis, Oregon State University, Corvalis, OR, 147 pp.

[2]Natanson, L.J., J.A. Sulikowski, J.R. Kneebone & P.C. Tsang. 2007. Age and growth estimates for the smooth skate, Malacoraja senta, in the Gulf of Maine. Environ Biol. Fish. 80:293-308.

[3]Bubley, W. 2010. Updated life history and population structure assessment of spiny dogfish, Squalus acanthias, in the Gulf of Maine. Ph.D. Dissertation. University of New Hampshire, Durham, Maine.

[4]Cailliet, G.M., Goldman, K.J. 2004. Age determination and validation in chodrichthyan fishes. In: Carrier J, Musick JA, Heithaus MR (eds) Biology of sharks and their relatives. CRC Press LLC, Boca Raton, FL, pp 399-447.

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The recommendations and general content presented in this poster do not necessarily represent the views or official position of the Department of Commerce, the National Oceanic and Atmospheric Administration, or the National Marine Fisheries Service.

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