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Author(s)	Nakamura, Kenta; Kawai, Toshio
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Morphological intraspecific variation of a softnose skate, *Bathyraja diplotaenia* (Ishiyama, 1952) (Rajiformes : Arhynchobatidae)

Kenta NAKAMURA[1] and Toshio KAWAI[2]

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Abstract

The softnose skate, *Bathyraja diplotaenia* (Ishiyama, 1952) (Rajiformes : Arhynchobatidae), was morphologically examined and described on the basis of 48 male (179.4–856 mm total length) and 45 female specimens (172.8–849 mm total length) to describe intraspecific variation with growth and distribution of placoid scales, alar thorn patch, and body color of the species. The results make clear that placoid scales on the dorsal side of the disc mostly disappear in specimens of 439.3–473.2 mm total length, the alar thorn patch appears in male specimens of 665–751 mm total length, and the body color changes in specimens of 363.6–653 mm total length. In addition, it reveals that the species starts to mature at about 500 mm total length and matures at about 750 mm total length based on growth of clasper length and presence of the alar thorn patch.

Key words : Body color, Placoid scales, Alar thorn patch, Clasper, Maturity, *T/S Oshoro-maru*, *T/S Hokusei-maru*

Introduction

Bathyraja diplotaenia (Ishiyama, 1952) inhabits bottoms of relatively deep-sea waters at 100–1,000 m depth from off Choshi, Chiba to Kushiro, Hokkaido, the Pacific coast of northern Japan, and off Hokkaido, the Okhotsk Sea (Ishiyama, 1952 ; Nakaya, 1983 ; Maeda and Tsutsui, 2003 ; Hatooka et al., 2013 ; Last et al., 2016). This species is characterized by the following characters : absence of scapular and orbital thorns ; 0–3 nuchal thorns ; 18–28 total tail thorns ; distance from cloaca to caudal-fin tip shorter than disc width ; deeply incised pelvic fin, and snout length 1.20–1.84 times anterior pelvic lobe ; long anterior pelvic lobe with its tip reaching or exceeding dilated side of posterior pelvic lobe ; absence of any blotches and spots on the dorsal side of body (Ishiyama, 1952, 1967 ; Matsubara, 1955 ; Nakaya, 1983, 1984 ; Ishihara and Ishiyama, 1985 ; Hatooka et al., 2013 ; Last et al., 2016). The distributional pattern of placoid scales on body surfaces is important for species identification in rajiform fishes (e.g., Hatooka et al., 2013 ; Last et al., 2016). On the other hand, although dorsal surface of the disc in young of *Bathyraja diplotaenia* is uniformly covered with placoid scales, and that in adults is almost naked (Ishiyama, 1952 ; Last et al., 2016), it is unclear when placoid scales disappear. Also, although the alar thorn patch situated at marginal area of the pectoral fins is present in adult males of the species, it is uncertain when the thorns appear (Ishiyama, 1952 ; Last et al., 2016). In addition, although body color is variable with growth in the species (Ishiyama, 1967), its variation has never been shown with photographs. Therefore, we describe these characters (distribution of placoid scales, alar thorn patch and body color) to make clear intraspecific variation with growth.

Materials and methods

Specimens examined in this study are deposited at the Hokkaido University Museum, Hakodate (HUMZ). Counts follow Hubbs and Ishiyama (1968), except Last et al. (2008) for vertebrae and pectoral- and pelvic-fin radials. Terminology of thorns follows Yearsley and Last (2016), and total tail thorns (median row of thorns + interdorsal thorns) follow Misawa et al. (2020). Proportional measurements follow Hubbs and Ishiyama (1968), and except these that follow Last et al. (2008) : distance from cloaca to caudal-fin tip, snout length, orbit diameter, orbit and spiracle length, snout to spiracle, ventral head length, ventral snout length, width of first gill opening, width of fifth gill opening, distance between first gill openings, distance between fifth gill openings, cloaca to pelvic-clasper insertion, length of anterior pelvic lobe, length of posterior pelvic lobe, pelvic base width, tail at midlength (width), tail at midlength (height), D2 origin to caudal-fin tip

[1] *School of Fisheries Sciences, Hokkaido University*
（北海道大学水産学部）
[2] *Faculty of Fisheries Sciences, Hokkaido University*
（北海道大学大学院水産科学研究院）

and caudal-fin length. Total length is abbreviated as TL. Measurements were made to the nearest 0.1 mm with dial and digital calipers and 1 mm with a metallic ruler for larger specimens which are longer than 600 mm TL. Vertebrae and radials were determined from radiographs.

Bathyraja diplotaenia (Ishiyama, 1952)

(Standard Japanese name : Ribon-kasube)
(Figs. 1-4 ; Tables 1, 2)

Diagnosis

Absence of scapular and orbital thorns ; 0-4 nuchal thorns ; 18-28 total tail thorns ; distance from cloaca to caudal-fin tip shorter than disc width ; deeply incised pelvic fin, and snout length 1.16-1.84 times anterior pelvic lobe ; long anterior pelvic lobe with its tip reaching or exceeding dilated side of posterior pelvic lobe ; absence of any blotches and spots on the dorsal side of body (Ishiyama, 1952, 1967 ; Matsubara, 1955 ; Nakaya, 1983, 1984 ; Ishihara and Ishiyama, 1985 ; Hatooka et al., 2013 ; Last et al., 2016 ; present study).

Materials

Males (48 specimens, 179.4-856 mm TL) : HUMZ 35015, 35029, 35044, 35056, 107234, 5 specimens, 557.9-665 mm TL, captured data unknown ; HUMZ 72532, 1, 623 mm TL, off Tohoku, 38°00′N, 142°10.05′E, 800-810 m depth, trawl, 6 Feb. 1978 ; HUMZ 90917, 1, 569.3 mm TL,

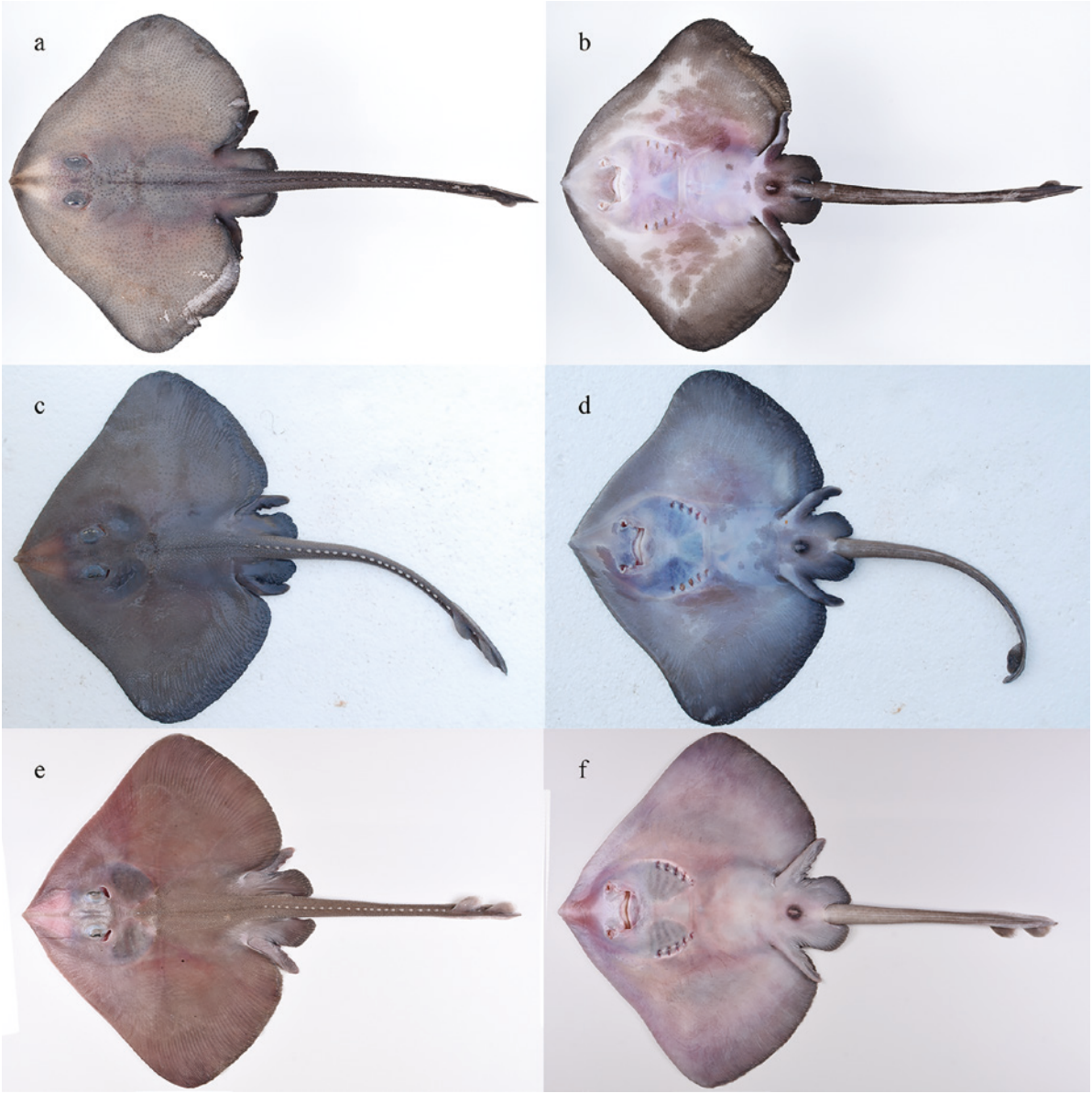

Fig. 1. Fresh specimens of *Bathyraja diplotaenia*. (a, b) HUMZ 231519, 262.6 mm TL, (c, d) HUMZ 206488, 405.3 mm TL, (e, f) HUMZ 230959, 611 mm TL. (a, c, e) dorsal and (b, d, f) ventral side.

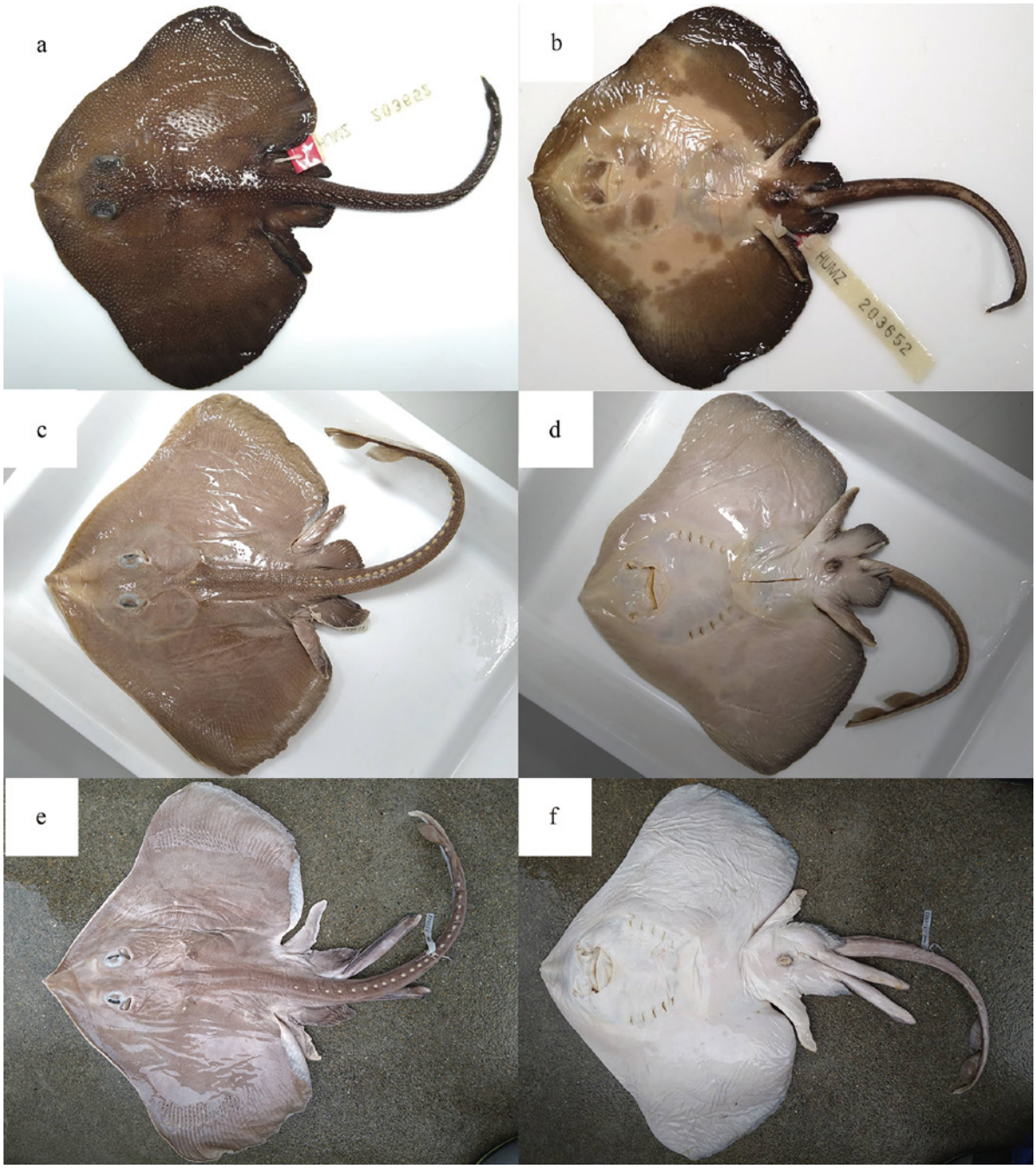

Fig. 2. Preserved specimens of *Bathyraja diplotaenia*. (a, b) HUMZ 203652, 182.4 mm TL, (c, d) HUMZ 203673, 492.5 mm TL, (e, f) HUMZ 126922, 751 mm TL. (a, c, e) dorsal and (b, d, f) ventral side.

300 m depth, trawl, 24 Dec. 1980 ; HUMZ 113007, 1, 856 mm TL, off Hachinohe, Aomori, 40°57.9′N, 141°59.8′E, 751 m depth, *T/S Hokusei-maru*, 6 Mar. 1988 ; HUMZ 126922, 1, 751 mm TL, off Urahoro, Hokkaido, 42°26.3′N, 144°05.5′E, 779 m depth, otter trawl, *T/S Oshoro-maru*, 6 Sep. 1993 ; HUMZ 136629, 136630, 2, 753–816 mm TL, off Tohoku, otter trawl, *T/S Hokusei-maru*, Apr. 1995 ; HUMZ 143448, 1, 772 mm TL, off Hachinohe, Aomori, 40°23.8′N, 142°18.0′E, 700 m depth, otter trawl, *T/S Oshoro-maru*, 6 Sep. 1995 ; HUMZ 151345, 151346, 2, 363.6–756 mm TL, off Tohoku ; HUMZ 152193, 1, 296.6 mm TL, off Kushiro, Hokkaido, 607 m depth, trawl, 5 Sep. 1997 ; HUMZ 152420, 1, 801 mm TL, off Tohoku, 622 m depth, trawl, 9 July 1997 ; HUMZ 154839, 154843, 2, 429.6–501.2 mm TL, off Kushiro, Hokkaido, 42°17.81′N, 143°54.47′E, 607 m depth, trawl, 5 Sep. 1997 ; HUMZ 164962, 1, 537.6 mm TL, off Hiroo, Hokkaido, 25 July 1999 ; HUMZ 177918, 1, 400.3 mm TL, off Tohoku, 37°44.25′N, 142°03.48′E–37°42.71′N, 142°04.14′E, 550–551 m depth, trawl, 21 Jan. 2001 ; HUMZ 181897, 1, 403.3 mm TL, off Tohoku, 41°15.70′N,

141°43.43′E–41°16.26′N, 141°42.91′E, 8 Nov. 1998 ; HUMZ 190119, 190122, 190123, 3, 219.0–287.4 mm TL, off Shiraoi, Hokkaido, 42°10.61′N, 141°37.95′E–42°13.48′N, 141°39.68′E, 700 m depth, otter trawl, *T/S Oshoro-maru*, 19 Sep. 2004 ; HUMZ 196419, 1, 590.7 mm TL, off Kushiro, Hokkaido, 42°31.2′N, 143°59.3′E–42°30.8′N, 145°59.0′E, 442–430 m depth, trawl, 13 June 2006 ; HUMZ 197401, 1, 788 mm TL, off Aomori, 41°13.42′N, 141°32.89′E, 560–564 m depth, 8 Nov. 1998 ; HUMZ 201136, 1, 395.9 mm TL, off Erimo, Hokkaido, 42°06.8′N, 141°40.1′E–42°09.10′N, 141°36.7′E, 771–685 m depth, otter trawl, *T/S Oshoro-maru*, 17 Oct. 2007 ; HUMZ 203652–203657, 6, 182.4–379.9 mm TL, off Tomakomai, Hokkaido, 42°04.4′N, 141°36.2′E–42°15.5′N, 141°39.4′E, 715 m depth, trawl, 1 Oct. 2008 ; HUMZ 203667, 203668, 2, 427.6–548.3 mm TL, off Tomakomai, Hokkaido, 42°14.6′N, 141°45.9′E–42°10.0′N, 141°38.2′E, 725 m depth, trawl, 26 Sep. 2008 ; HUMZ 203673, 1, 492.5 mm TL, off Tomakomai, Hokkaido, 42°15.0′N, 141°42.4′E–42°05.5′N, 141°38.8′E, 714–717 m depth, trawl, 1 Oct. 2008 ; HUMZ 205245, 1, 196.5 mm TL, off Hokkaido, 568–578 m depth, trawl, 3 July 2009 ; HUMZ 206490, 1, 308.6 mm TL, off Tomakomai, Hokkaido, 42°14.09′N, 141°43.01′E–42°13.84′N, 141°37.46′E, 740 m depth, otter trawl, *T/S Oshoro-maru*, 5 Oct. 2009 ; HUMZ 206491, 206492, 2, 214.1–280.9 mm TL, off Tomakomai, Hokkaido, 42°10.16′N, 141°36.47′E–42°06.20′N, 141°36.62′E, 600 m depth, otter trawl, *T/S Oshoro-maru*, 4 Oct. 2009 ; HUMZ 215060, 1, 179.4 mm TL, off Hiroo, Hokkaido, 42°17.82′N, 143°55.07′E–42°18.22′N, 143°55.31′E, 5 June 2012 ; HUMZ 226437, 226438, 2, 242.1–260.2 mm TL, off Hiroo, Hokkaido, otter trawl, *T/S Oshoro-maru*, 24 Sep. 2015 ; HUMZ 230041, 1, 195.4 mm TL, off Urakawa, Hokkaido, 41°54.5′N, 141°50.6′E–42°02.0′N, 141°38.2′E, 819 m depth, otter trawl, *T/S Oshoro-maru*, 29 Sep. 2018 ; HUMZ 230953, 1, 180.5 mm TL, off Tomakomai, Hokkaido, 41°58.9′N, 141°35.3′E–41°52.7′N, 141°43.8′E, 715–860 m depth, otter trawl, *T/S Oshoro-maru*, 17 Oct. 2019 ; HUMZ 231519, 1, 262.6 mm TL, off Tomakomai, Hokkaido, 42°05.2′N, 141°35.9′E–41°57.9′N, 141°39.3′E, 700–755 m depth, otter trawl, *T/S Oshoro-maru*, 17 Sep. 2020 ; HUMZ 231702, 231703, 2, 185.2–574.6 mm TL, off Tomakomai, Hokkaido, 41°53.2′N, 141°42.0′E–41°59.4′N, 141°39.2′E, 850 m depth, otter trawl, *T/S Oshoro-maru*, 17 Sep. 2020.

Females (45 specimens, 172.8–849 mm TL) : HUMZ 35043, 97434, 98424, 3, 481.0–833 mm TL, captured data unknown ; HUMZ 63433, 63434, 2, 838–849 mm TL, off Muroran, Hokkaido, 320 m depth, 23 Aug. 1977 ; HUMZ 90920, 1, 301.7 mm TL, 300 m depth, trawl, 24 Dec. 1980 ; HUMZ 97307, 1, 727 mm TL, off Hiroo, Hokkaido, 42°02.9′N, 143°45.5′E, 475 m depth, otter trawl, *T/S Hokusei-maru*, 6 Apr. 1983 ; HUMZ 105372, 1, 807 mm TL, Funka Bay, Hokkaido, 41°55.22′N, 149°29.46′E, 399 m depth, 3 Sep. 1985 ; HUMZ 107233, 1, 657 mm TL ; HUMZ 126923–126925, 3, 379.4–440.6 mm TL, off Hiroo, Hokkaido, 42°24.5′N, 143°58.6′E, 580–630 m depth, otter trawl, *T/S Oshoro-maru*, 6 Sep. 1993 ; HUMZ 154837, 1, 453.5 mm TL, off Kushiro, Hokkaido, 42°18.4′N, 143°54.6′E–42°19.9′N, 143°55.9′E, 710 m depth, trawl, 7 Sep. 1996 ; HUMZ 154838, 154840–154842, 4, 409.3–473.2 mm TL, off Kushiro, Hokkaido, 42°17.81′N, 143°54.47′E, 607 m depth, trawl, 5 Sep. 1997 ; HUMZ 177012, 1, 172.8 mm TL, off Futaba, Fukushima, 37°29.05′N, 142°08.11′E–37°28.97′N, 142°06.10′E, 650–652 m depth, trawl, 18 Apr. 2000 ; HUMZ 177312, 1, 653 mm TL, off Hiroo, Hokkaido, 41°48.34′N, 143°42.59′E, 14 July 2000 ; HUMZ 177916, 177917, 2, 445.3–585.3 mm TL, off Minamisoma, Fukushima, 37°42.71′N, 142°04.14′E, 550–551 m depth, trawl, 16 Apr. 2000 ; HUMZ 190120, 190121, 2, 196.6–236.9 mm TL, off Shiraoi, Hokkaido, 42°10.61′N, 141°37.95′E–42°13.48′N, 141°39.68′E, 700 m depth, otter trawl, *T/S Oshoro-maru*, 19 Sep. 2004 ; HUMZ 203651, 203666, 2, 306.3–321.4 mm TL, off Tomakomai, Hokkaido, 42°04.4′N, 141°36.2′E–42°15.5′N, 141°39.4′E, 715 m depth, trawl, 1 Oct. 2008 ; HUMZ 203669–203672, 4, 186.1–517.7 mm TL, off Tomakomai, Hokkaido, 42°15.0′N, 141°42.4′E–42°05.5′N, 141°38.8′E, 714–717 m depth, trawl, 1 Oct. 2008 ; HUMZ 206285, 206286, 2, 327.5–360.2 mm TL, off Tomakomai, Hokkaido, 42°12.79′N, 141°41.05′E–42°13.69′N, 141°36.13′E, 800 m depth, otter trawl, *T/S Oshoro-maru*, 29 Sep. 2009 ; HUMZ 206300–206302, 3, 227.8–417.2 mm TL, off Tomakomai, Hokkaido, 42°13.39N, 141°41.58′E–42°11.98′N, 141°46.33′E, 580–760 m depth, otter trawl, *T/S Oshoro-maru*, 30 Sep. 2009 ; HUMZ 206308, 1, 538.7 mm TL, off Tomakomai, Hokkaido, 41°58.80′N, 141°37.34′E–41°51.89′N, 141°38.33′E, 750–790 m depth, otter trawl, *T/S Oshoro-maru*, 29 Sep. 2009 ; HUMZ 206488, 206489, 2, 348.0–405.3 mm TL, off Tomakomai, Hokkaido, 42°14.09′N, 141°43.01′E–42°13.84′N, 141°37.46′E, 740 m depth, otter trawl, *T/S Oshoro-maru*, 5 Oct. 2009 ; HUMZ 215061, 1, 215.2 mm TL, off Hidaka, Hokkaido, 42°17.29′N, 141°53.54′E–42°17.61′N, 143°48.58′E, 6 June 2012 ; HUMZ 224649, 1, 439.3 mm TL, off Tomakomai, Hokkaido, 42°05.8′N, 141°35.6′E–42°09.1′N, 141°35.7′E, 710 m depth, otter trawl, *T/S Oshoro-maru*, 19 Oct. 2014 ; HUMZ 230040, 1, 186.0 mm TL, off Urakawa, Hokkaido, 41°54.5′N, 141°50.6′E–42°02.0′N, 141°38.2′E, 819 m depth, otter trawl, *T/S Oshoro-maru*, 29 Sep. 2018 ; HUMZ 230952, 1, 191.9 mm TL, off Tomakomai, Hokkaido, 41°58.9′N, 141°35.3′E–41°52.7′N, 141°43.8′E, 715–860 m depth, otter trawl, *T/S Oshoro-maru*, 17 Oct. 2019 ; HUMZ 230959, 230960, 2, 611–629 mm TL, off Tomakomai, Hokkaido, 41°59.0′N, 141°35.1′E–41°53.5′N, 141°42.5′E, 750 m depth, otter trawl, *T/S Oshoro-maru*, 18 Oct. 2019 ; HUMZ 230961, 1, 580.0 mm, off Tomakomai, Hokkaido, 41°54.5′N, 141°41.4′E–41°50.7′N, 141°52.8′E, 860–910 m depth, otter

trawl, *T/S Oshoro-maru*, 18 Oct. 2019 ; HUMZ 231520, 1, 237.3 mm TL, off Tomakomai, Hokkaido, 42°05.2′N, 141°35.9′E–41°57.9′N, 141°39.3′E, 700–755 m depth, otter trawl, *T/S Oshoro-maru*, 17 Sep. 2020.

Description

Counts and proportional measurements are listed in Tables 1, 2.

Placoid scales. In specimens of 172.8–431.2, 440.6, 445.3 and 473.2 mm TL, dorsal side of disc uniformly covered with placoid scales (Figs. 1a, 2a). In specimens of 439.3, 453.5 and 481.0–856 mm TL, marginal area of disc, area above synarchual and interocular space covered with placoid scales, other parts of disc without scales (Figs. 1c, d, 2c, d). In some specimens of 439.3–590.7 mm TL (HUMZ 35056, 98424, 107234, 154837, 154839, 164962, 177917, 196419, 203668, 203672, 203673, 206308, 224649), rudimentary placoid scales or its traces present on the scaleless area of disc. In all specimens examined, ventral side of disc and anterior pelvic lobe on dorsal and ventral sides smooth without scales ; dorsal side of posterior pelvic lobe without scales or slightly covered with placoid scales, its ventral side smooth without scales ; dorsal side of tail uniformly covered with placoid scales, ventral side smooth without scales ; dorsal fin slightly covered with placoid scales.

Alar thorn patch (Fig. 3a). In males of 751 mm TL and greater, alar thorn patch present on marginal area of each pectoral fin. In males of 665 mm TL and less, and all females, the patch absent.

Color in 50% isopropyl alcohol after fixation by 10% formalin (Fig. 2). 172.8–363.6 mm TL (Fig. 2a, b) : dorsal side of disc, pelvic fin and tail uniformly dark brown ; ventral side of disc divided into dark part (black or dark brown) of marginal area and light part (white or light brown) with dark brown spots of center area (without spots in HUMZ 206300) ; anterior margin and base of ventral side of anterior pelvic lobe white or light brown, the other parts dark brown ; ventral side of posterior pelvic lobe uniformly dark brown ; base of ventral side of tail white or dark brown, and the other parts dark brown or light brown ; dorsal and caudal fins, and lateral fold dark brown ; thorns on dorsal side of body white ; cloaca white or light brown surrounded by dark brown ; clasper in only males dark brown on both dorsal and ventral sides, but the tip white. 379.4–856 mm TL (Fig. 2 c–f) : dorsal side of disc, posterior pelvic lobe and tail brown or gray ; margin of eyes and spiracles, and snout white ; dorsal side of anterior pelvic lobe white or similar color with dorsal side of disc ; posterior marginal area of ventral side of disc dark brown ; the remaining part of ventral side of disc uniformly white, except for specimens of 379.4–501.2, 585.3 and 653 mm TL (Fig. 2d) which have similar pattern but faded with specimens of 172.8–363.6 mm TL ; ventral side of anterior pelvic lobe uniformly white, or white anteriorly and light brown posteriorly ; ventral side of posterior pelvic lobe white except for marginally dark brown ; ventral side of tail brown or light brown ; dorsal and caudal fins similar with dorsal side of disc ; lateral fold white or light brown ; thorns on dorsal side of body white or brown ; cloaca white surrounded by dark brown ; clasper on dorsal side in only males similar with posterior pelvic lobe, on ventral side uniformly white, or dark brown except white mid area ; tip of clasper white.

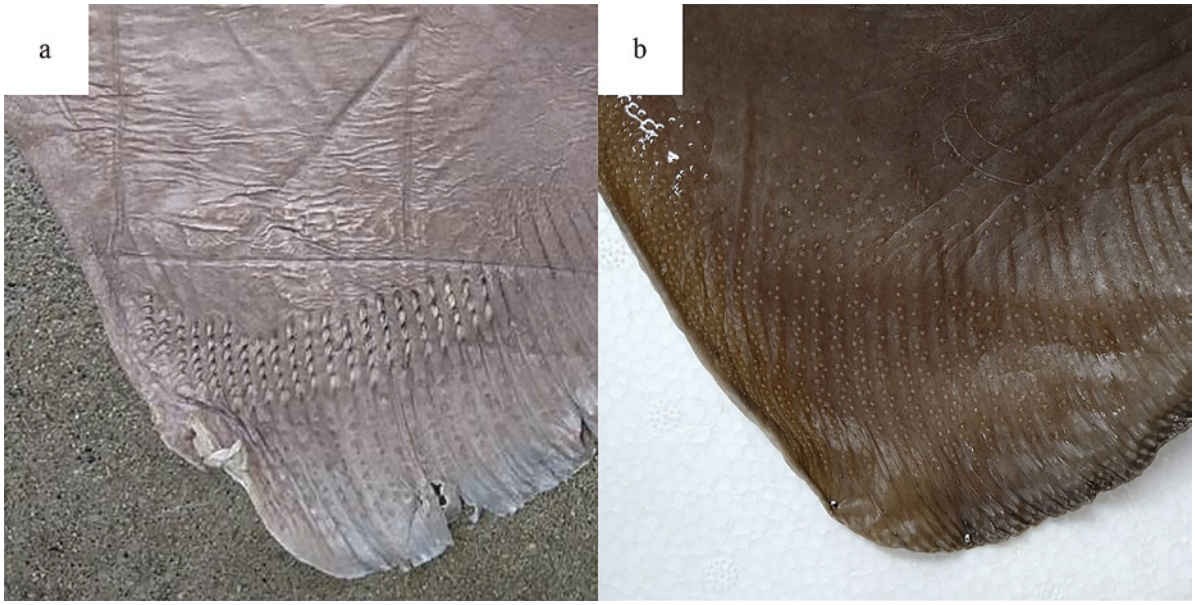

Fig. 3. Alar thorn patch. (a) present, HUMZ 136629, 816 mm TL, (b) absent, HUMZ 231703, 574.6 mm TL.

Table 1. Measurements of *Bathyraja diplotaenia.*

	Males *n*=47	Females *n*=45
Total length (mm)	179.4–856	172.8–849
Measurements (% TL)		
Disc width	61.4–73.0 (*n*=42)	61.5–72.4 (*n*=44)
Disc length	47.1–53.7 (*n*=45)	47.2–55.4
Anterior projection	27.1–31.4 (*n*=46)	26.3–32.5
Trunk length	24.2–30.2 (*n*=45)	24.0–30.2 (*n*=44)
Mouth to tail	30.5–36.5 (*n*=46)	29.4–36.0 (*n*=44)
Precaudal length	42.4–47.9 (*n*=46)	41.8–49.4 (*n*=44)
Distance from cloaca to caudal-fin tip	52.0–57.6	50.6–57.9 (*n*=44)
Head length (dorsal side)	16.5–19.5	16.9–19.7
Snout length	11.0–13.9	10.9–14.2
Orbit diameter	3.9–5.5	3.8–5.3 (*n*=44)
Between orbits	3.2–4.3	3.1–4.5 (*n*=44)
Orbit and spiracle length	4.7–6.3	4.6–6.1 (*n*=44)
Snout to spiracle	16.2–18.9	16.3–19.4 (*n*=44)
Spiracle length	2.5–3.6	2.5–3.5 (*n*=44)
Between spiracles	5.8–7.4	5.8–7.2
Eyeball length	3.1–5.4	3.0–4.9
Ventral head length	23.8–27.5	24.0–28.8
Ventral snout length	10.2–13.8	10.5–14.8
Prenarial length	8.7–11.5	9.3–12.7
Internarial distance	6.1–7.8	6.2–8.1
Nasal-curtain length	3.0–4.8	2.9–5.0
Nasal-curtain width	7.0–9.3	6.9–9.1
Between nasal fimbriae	3.9–6.0	3.9–5.3
Mouth width	5.7–7.8	5.6–7.5
Width of first gill opening	1.1–1.8	1.2–1.8 (*n*=43)
Width of fifth gill opening	0.9–1.4	0.8–1.4 (*n*=44)
Distance between first gill openings	13.4–15.6	13.6–16.1 (*n*=43)
Distance between fifth gill openings	7.9–9.4 (*n*=46)	8.0–9.6 (*n*=44)
Clasper length	5.6–24.4	–
Cloaca to pelvic-clasper insertion	4.0–9.5 (*n*=46)	–
P2 width	14.4–17.6 (*n*=46)	15.1–17.5 (*n*=43)
P2 length	7.1–12.9 (*n*=46)	7.7–11.0 (*n*=44)
Anterior P2 lobe	7.9–10.6 (*n*=46)	8.1–10.4 (*n*=44)
Length of anterior pelvic lobe	14.6–16.5 (*n*=46)	14.0–16.6 (*n*=44)
Length of posterior pelvic lobe	13.2–20.2 (*n*=46)	12.9–17.7 (*n*=44)
Pelvic base width	5.5–7.4 (*n*=46)	5.4–8.4 (*n*=42)
Tail width, end P2	3.6–5.1	3.8–4.8 (*n*=43)
Tail depth, end P2	2.6–3.7	2.4–3.4 (*n*=42)
Tail at midlength (width)	1.7–2.6 (*n*=46)	1.6–2.5 (*n*=44)
Tail at midlength (height)	1.4–1.9 (*n*=46)	1.4–1.9 (*n*=44)
Tail width, origin D1	1.0–2.1	1.3–2.2 (*n*=44)
Tail depth, origin D1	1.1–1.5 (*n*=45)	1.1–1.5 (*n*=44)
Predorsal tail length	37.7–42.3	36.2–43.2 (*n*=44)
D1 origin to tail tip	12.6–19.9	13.6–18.7
D2 origin to caudal-fin tip	6.6–13.8	7.6–12.9
D1 basal length	4.0–5.2 (*n*=42)	3.9–5.3
Between D bases	0.5–2.0 (*n*=42)	0.4–2.2
D2 basal length	3.3–5.1 (*n*=42)	3.3–5.0
Caudal-fin length	2.3–8.0 (*n*=44)	2.3–7.7 (*n*=41)
D1 vertical height	1.6–3.0 (*n*=44)	1.4–3.1 (*n*=43)
D2 vertical height	1.7–3.2 (*n*=44)	1.5–3.3 (*n*=42)
C vertical height	0.2–1.0	0.4–0.9 (*n*=43)
Lateral fold length	18.2–34.9	15.2–30.0 (*n*=44)
Lateral fold width	0.3–0.9	0.3–1.0

Table 2. Counts of *Bathyraja diplotaenia.*

	Males *n*=48	Females *n*=45
Total length (mm)	179.4–856	172.8–849
Counts		
Scapular thorns	0	0
Orbital thorns	0	0
Median row + interdorsal = total tail thorns	19–26 + 0–1 = 19–26	18–26 + 0–1 = 18–26
Nuchal thorns	0–4	0–3
Rows of alar thorn patch	15–24 (*n*=8)	–
Tooth rows of upper jaw	29–41	29–40
Tooth rows of lower jaw	26–37	27–42
Trunk centra	34–35 (*n*=6)	33–36 (*n*=7)
Predorsal caudal centra	69–74 (*n*=6)	68–76 (*n*=7)
Predorsal centra	103–108 (*n*=6)	101–110 (*n*=7)
Centra between origins of dorsal fins	11–13 (*n*=6)	11–13 (*n*=7)
Total diplospondylous centra	106–114 (*n*=6)	105–117 (*n*=7)
Total vertebral centra	140–148 (*n*=6)	135–150 (*n*=7)
Propterygial radials	33–35 (*n*=6)	33–36 (*n*=7)
Mesopterygial radials	17–19 (*n*=6)	19–21 (*n*=7)
Metapterygial radials	24–28 (*n*=6)	24–27 (*n*=7)
Pelvic–fin radials	1, 17–21 (*n*=6)	1, 16–22 (*n*=7)

Discussion

Placoid scales

We found that the dorsal side of disc is uniformly covered with placoid scales in specimens of 431.2 mm TL and less, and is mostly naked except for the marginal area, area above the synarchual and interocular space in specimens of 481.0 mm TL and greater. On the other hands, both conditions are found in specimens of 439.3–473.2 mm TL. Therefore, placoid scales on the dorsal side of disc mostly disappear in specimens of 439.3–473.2 mm TL.

Alar thorn patch

We found that the alar thorn patch appears in specimens of 665–751 mm TL because the minimum size of specimen in having an alar thorn patch is 751 mm TL, and maximum size lacking the patch is 665 mm TL.

Body color

We show that the color of the dorsal side of disc, margin of eyes and spiracles, snout, clasper, tail, dorsal, pelvic and caudal fins, and lateral fold changes in specimens of 363.6–379.4 mm TL. In addition, we found that specimens of 379.4–501.2, 585.3 and 653 mm TL have a dark marginal area, and light central area with dark brown spots on the ventral side of disc, that color pattern is similar but faded with specimens of 172.8–363.6 mm TL. Therefore, body color changes in specimens of 363.6–653 mm TL.

Relationships between maturity and variation with growth

Maturing begins in ca. 500 mm TL because clasper length becomes longer when total length exceeds ca. 500 mm (Fig. 4). At the almost the same period, it reveals that most placoid scales on the dorsal side of disc disappear. Presence of developed alar thorn patch has been known in only matured males (Mabragaña et al., 2002 ; Ruocco et al., 2006 ; Last et al., 2016). In this study, alar thorn patch is present in specimen of 751 mm TL and greater. In addition, growth of clasper length stops when total length exceeds ca. 750 mm (Fig. 4). Consequently, we conclude that the species matures in ca. 750 mm TL and body color changes completely before maturity.

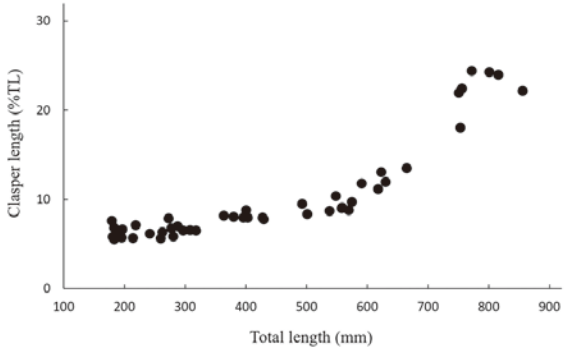

Fig. 4. Relationships of clasper length against total length.

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