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Comparative Analysis of Morphometric Characteristics of Scorpaenidae and Gobioninae

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ABSTRACT : Measurements of closely related sets of classical and truss dimensions were analyzed to discriminate species of scorpaenidae including the dark banded rockfish, *Sebastes inermis*, the black rockfish, *S. schlegeli*, and gobioninae including the striped shiner, *Pungtungia herzi*, and the slender shiner, *Pseudopungtungia tenuicorpa*. The measurements of the dimensions were arc sin square root transformed, and compared as a function of the standard length of each species for statistical analysis. For values of the classical dimensions of the rockfish, 6 were greater for the dark banded rockfish than for the black rockfish, 1 value was smaller for the former, and for 2 values there was no statistically significant difference ($P > 0.05$). For values of the classical dimensions of the shiners, 9 values were greater for the striped shiner than for the slender shiner, 2 values were smaller for the former, and for 1 value there was no statistically significant difference ($P > 0.01$). For values of the truss dimensions of the rockfish, 6 were greater for the dark banded rockfish than for the black rockfish, 1 was smaller for the former, and for 4 values there was no statistically significant difference ($P > 0.05$). For values of the truss dimensions of the shiners, 13 values were greater for the striped shiner than for the slender shiner, 3 values were smaller for the former, and for 6 values there was no statistically significant difference ($P > 0.01$). The dimension sets used in this study may be useful as taxonomic indicators for discriminating among fish species in Korea.

Key words : Classical dimension, *Pungtungia herzi*, *Pseudopungtungia tenuicorpa*, *Sebastes inermis*, *S. schlegeli*, Truss dimension

INTRODUCTION

Morphological differences based on general body type or unusual anatomical forms have been used to distinguish and compare among species and groups (Straüss & Bond, 1990). Both truss (Straüss & Bookstein, 1982) and classical (Hubbs & Lagler, 1947) dimensions have been used to describe fish body shape. Classical dimensions are the most used in studies of morphometric characteristics of fish (Straüss & Bond, 1990; Park et al., 2001a, 2004, 2007). Truss dimensions, which include components of body depth and length along the longitudinal axis, have theoretical advantages over classical morphometric characters in discriminating among groups (Humphries et al., 1981; Straüss & Bookstein, 1982; Winans, 1984; Currens et al., 1989; Park et al., 2001a, 2004).

Basic understanding of morphometric characteristics has been based on three aspects: (i) identifying unidentified

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taxa such as unknown hybrids, and distinguishing sexes or species; (ii) investigating mutated forms of groups and species; and (iii) identifying and classifying biotypic associations (Straüss, 1985; Winans, 1985; Taylor et al., 1986; Park et al., 1997, 2001a, 2001b, 2003, 2004, 2006a, 2006b).

Taxonomically, the dark banded rockfish, *Sebastes inermis* belongs to the Scorpaeniformes (family Scorpaenidae) and is an ovoviviparous teleost. It is distributed throughout the seas of Korea and Southern Hokkaido (Japan) (Jung, 1977; Choi et al., 2002). It is an economically important species in coastal environments and is also reared in aquaculture. As dark banded rockfish is abundant it is possible to collect the fish throughout the year on the Southern coast of Korea, and it is a promising species for resources enhancement, including marine ranching (Jung, 1977; Lee & Kim, 1992).

The black rockfish, *S. schlegeli* is also ovoviviparous and a member of the Scorpaenidae, and is distributed throughout the Korea, Japan, China and Yellow seas; in Korean waters it is a resident coastal fish (Jung, 1977; National Fisheries Research & Development Agency, 1994). The black rockfish occurs throughout winter in all coastal waters of Korea because it is large, exhibits rapid growth amongst rockfish types, and is resilient to low temperatures. It is thus an appropriate target species for aquaculture and marine ranching (Park et al., 2004).

The striped shiner, *Pungtungia herzi* is a far eastern freshwater species belonging to the Cypriniformes (family Gobioninae), and is widely distributed throughout Korea, China, and Japan. The slender shiner, *Pseudopungtungia tenuicorpa* has the same taxonomic affiliation, but is an endemic Korean species restricted to the Han and Imjin rivers (Kim & Park, 2002).

Basic ichthyological and biosystematics studies of the two rockfish species have been reported. Lee & Kim (1992) and Park et al. (2012) reported reproduction and embryonic development, early growth and eye development of dark banded rockfish. In addition, microstructural growth of larval black rockfish was reported in 2000 (Lee & Kim, 2000). Comparative study of striped shiner and slender shiner has been made of their phylogenetic relationships, based on urohyal characters (Kim & Kang, 1989). However, detailed comparative morphological studies of the striped and slender shiner have not been conducted. Dark banded rockfish and black rockfish are one of seawater fish inhabited widely, and are breeding widely in Korea (Lee & Kim, 1992). In addition, external morphology of two rockfish is similar, so that need to research two rockfish (Lee & Kim, 2000; Park et al., 2012). Striped shiner and slender shiner are one of freshwater fish inhabited widely, and differences of morphometric characteristic between striped shiner and slender shiner are not shown nearly (Kim & Kang, 1989). Therefore, in this study we investigated and compared the morphological features of these species in Korea, using both classical and truss dimensions. The objectives were to identify those morphometric characteristics that differ significantly between the two Scorpaenidae species, and to assess the origin of the two shiner species.

MATERIALS AND METHODS

1. Experimental fish

Dark banded rockfish, *Sebastes inermis* and black rockfish, *S. schlegeli* were reared and maintained at the Fishery Genetics & Breeding Science Laboratory, Korea Maritime and Ocean University (KMOU), Korea. The rockfish were reared in 1100 L FRP circular culture tanks (118 cm diameter, 101 cm height), each of which contained 50 fish. During rearing the dissolved oxygen concentration was ≥ 9.7 mL/L, the pH was 7.52–8.32, and the water temperature was maintained at 20.5±0.5℃. The fish were fed twice daily with extruded flounder pellets (type EP, Jeil Feed, Korea).

Specimens of striped shiner, *Pungtungia herzi* and slender shiner, *Pseudopungtungia tenuicorpa* were collected in July

2010 from a headwater tributary of the Imjin River (Jinsang-ri, Gunnam-myeon, Yeonchen-gun, Gyenggi-do, Korea), which discharges into Soyang Lake, and from Bukcheon (Buk-meon, Inje-gun, Gangweon-do, Korea). Specimens were also reared at the Fishery Genetics & Breeding Science Laboratory, KMOU, Korea. Most samples were randomly collected by trapping and hand netting. And digital pictures were taken for selected samples of each species using copystand and a Nikon D80 camera (D80, Nikon, Japan; Figs. 3 and 4).

2. Measurement of morphometric characteristics

Fish feeding was halted one day prior to morphometric analysis. Fifty fish of each species were collected and anaesthetized with a mixture of 500 ppm lidocaine-HCl (Hongseong Pharmaceuticals, Korea) and 1,000 ppm $NaHCO_3$ (Sigma, USA), following the method of Park et al. (2004). The morphometric characteristics (including both classical and truss dimensions) used in an experiments concerning starvation in the Chinese minnow, *Rhynchocypris oxycephalus*, were applied in the morphometric analysis in the present study (Park et al., 2001a, 2004). As shown in Figs. 1 and 2, the morphometric characteristics of each species were measured to the nearest 1.0 mm, 0.1 mm using a digital vernier caliper (CD-20CP, Mitutoyo, Japan), respectively.

Table 1. Body shape dimensions for the dark banded rockfish, *Sebastes inermis* and the black rockfish, *S. schlegeli*

Standard length	Ls
Eye diameter	ED
Classical dimension	
Direct distance between the anterior edge of the upper lip and the posterior end of supraoccipital	DALPS
Direct distance between the anterior edge of the upper lip and the anterior insertion of the dorsal fin	DALAD
Direct distance between the anterior edge of the upper lip and the margin of opercular cover	DALMO
Direct distance between the anterior edge of the upper lip and the posterior insertion of the dorsal fin	DALPD
Direct distance between the anterior edge of the upper lip and the base of pectoral fin	DALBP
Direct distance between the anterior edge of the upper lip and the anterior insertion of the ventral fin	DALAV
Direct distance between the anterior edge of the upper lip and the posterior insertion of the anal fin	DALPA
Direct distance between the anterior edge of the upper lip and the anterior insertion of the anal fin	DALAA
Caudal peduncle height	CH
Truss dimension	
Direct distance between the anterior edge of the upper lip and the posterior end of supraoccipital	DALPS
Direct distance between the posterior end of suparoccipital and the margin of opercular cover	DPSMO
Direct distance between the anterior insertion of the dorsal fin and the posterior insertion of the dorsal fin	DADPD
Direct distance between the anterior insertion of the dorsal fin and posterior insertion of the anal fin	DADPA
Direct distance between the anterior insertion of the dorsal fin and the anterior insertion of the anal fin	DADAA
Direct distance between the anterior insertion of the ventral fin and the anterior insertion of the anal fin	DAVAA
Direct distance between the anterior insertion of the ventral fin and the posterior insertion of the dorsal fin	DAVPD
Direct distance between the anterior insertion of the anal fin and the posterior insertion of the anal fin	DAAPA
Direct distance between the anterior insertion of the anal fin and the posterior insertion of the dorsal fin	DAAPD
Direct distance between the posterior insertion of the dorsal fin and the posterior insertion of the anal fin	DPDPA
Caudal peduncle height	CH

Nine classical dimensions were measured for the rockfish species (DALPS, DALAD, DALAA, DALAV, DALMO, DALPD, DALBP, DALPA, and CH), while for the shiner species 12 measurements were made (DALPS, DALAD, DALAA, DALAV, DALMO, DALDC, DALAP, DALPM, DADAV, DPDPL, CH, and DPLPA) (Tables 1 and 2; Figs. 1a and 2a).

Eleven truss dimensions were measured for the rockfish species (DALPS, DPSMO, DADPD, DADPA, DADAA, DAVAA, DAVPD, DAAPA, DAAPD, DPDPA, and CH), while for the shiner species 22 measurements were made (DALPS, DALPM, DPSAD, DPSAV, DPSAP, DPSPM, DADPD, DADAA, DADAV, DADAP, DPDDC, DPDVC, DPDPA, DAAPD, DAVPD, CH, DDCPA, DVCPA, DAAPA, DAVAA, DAVAP, and DAPPM) (Tables 1 and 2; Figs. 1b and 2b). In addition, the standard length (Ls) was measured for each species (Tables 1 and 2; Figs. 1 and 2), and the eye diameter (ED) was measured for the rockfish species (Table 1; Fig. 1).

3. Statistical analysis

Data on the morphometric traits of each species were arc sin square root transformed, and analyzed relative to the standard length (Ls) of each species (Park et al., 2001a, 2001b, 2007). To assess the statistical significance of differences in measurements and average values of each parameter we used a one-way ANOVA (SPSS 9.0, SPSS Inc., USA). We used Duncan's multiple range test ($P < 0.05$) for the rockfish species, and for the shiner species the Sidak pairwise test was used for multiple comparisons; differences between means were regarded as significant at $P < 0.01$.

RESULTS AND DISCUSSION

The average Ls was 13.6±1.05 cm for dark banded rockfish, *Sebastes inermis*, 14.9±1.31 cm for black rockfish, *S. schlegeli*, 68.2±4.34 cm for striped shiner, *Pungtungia herzi*, and 53.1±3.56 cm for slender shiner *Pseudopungtungia tenuicorpa*, respectively. The comparative results for the Ls and the classical and truss dimensions for all species are shown in Tables 3 and 4.

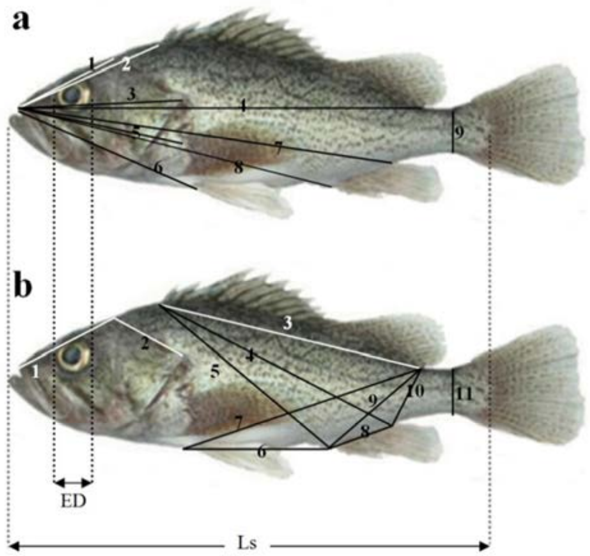

Fig. 1. Truss and classical dimensions measured for the dark banded rockfish, *Sebastes inermis* and the black rockfish, *S. schlegeli.* (a) classical dimensions: 1, DALPS; 2, DALAD; 3, DALMO; 4, DALPD; 5, DALBP; 6, DALAV; 7, DALPA; 8, DALAA; 9, CH. (b) truss dimensions: 1, DALPS; 2, DPSMO; 3, DADPD; 4, DADPA; 5, DADAA; 6, DAVAA; 7, DAVPD; 8, DAAPA; 9, DAAPD; 10, DPDPA; 11, CH. Refer to Table 1 for details of the dimensions.

The measured values of the classical dimensions DALPS/Ls, DALAD/Ls, DALPD/Ls, DALAV/Ls and DALPA/Ls for the dark banded rockfish were larger than those for the black rockfish. The value of dark banded rockfish for classical dimension (namely measurement items of body length based on body axis) was larger than that of black rockfish of body (Table 3; Fig. 3). There was no significant difference between dark banded rockfish and black rockfish for the classical traits DALBP and DALAA (from the premaxilla to the basal area of the pectoral fin and the start of the base of the anal fin, respectively; Table 3; Fig. 3) ($P > 0.05$). The results for measurement of classical dimensions in the two shiner species are shown in Table 4. The values of DALPS/Ls, DALAD/Ls, DALDC/Ls, DALAA/Ls, DALAV/

Table 2. Body shape dimensions for the striped shiner, *Pungtungia herzi* and the slender shiner, *Pseudopungtungia tenuicorpa*

Standard length	Ls
Classical dimension	
Direct distance between the anterior edge of the upper lip and the posterior end of supraoccipital	DALPS
Direct distance between the anterior edge of the upper lip and the anterior insertion of the dorsal fin	DALAD
Direct distance between the anterior edge of the upper lip and the dorsal origin of caudal fin	DALDC
Direct distance between the anterior edge of the upper lip and the anterior insertion of the anal fin	DALAA
Direct distance between the anterior edge of the upper lip and the anterior insertion of the ventral fin	DALAV
Direct distance between the anterior edge of the upper lip and the anterior insertion of the pectoral fin	DALAP
Direct distance between the anterior edge of the upper lip and the posterior end of maxillary	DALPM
Direct distance between the anterior edge of the upper lip and the margin of opercular cover	DALMO
Direct distance between the anterior insertion of the dorsal fin and the anterior insertion of the ventral fin	DADAV
Direct distance between the posterior insertion of the dorsal fin and the most posterior scale in lateral line	DPDPL
Caudal peduncle height	CH
Direct distance between the most posterior scale in lateral line and the posterior insertion of anal fin	DPLPA
Truss dimension	
Direct distance between the anterior edge of the upper lip and the posterior end of supraoccipital	DALPS
Direct distance between the anterior edge of the upper lip and the posterior end of maxillary	DALPM
Direct distance between the posterior end of supraoccipital and the anterior insertion of the dorsal fin	DPSAD
Direct distance between the posterior end of supraoccipital and the anterior insertion of the ventral fin	DPSAV
Direct distance between the posterior end of supraoccipital and the anterior insertion of the pectoral fin	DPSAP
Direct distance between the posterior end of supraoccipital and the posterior end of maxillary	DPSPM
Direct distance between the anterior insertion of the dorsal fin and the posterior insertion of the dorsal fin	DADPD
Direct distance between the anterior insertion of the dorsal fin and the anterior insertion of the anal fin	DADAA
Direct distance between the anterior insertion of the dorsal fin and the anterior insertion of the ventral fin	DADAV
Direct distance between the anterior insertion of the dorsal fin and the anterior insertion of the pectoral fin	DADAP
Direct distance between the posterior insertion of the dorsal fin and the dorsal origin of caudal fin	DPDDC
Direct distance between the posterior insertion of the dorsal fin and the ventral origin of caudal fin	DPDVC
Direct distance between the posterior insertion of the dorsal fin and the posterior insertion of anal fin	DPDPA
Direct distance between the anterior insertion of the anal fin and the posterior insertion of the dorsal fin	DAAPD
Direct distance between the anterior insertion of the ventral fin and the posterior insertion of the dorsal fin	DAVPD
Caudal peduncle height	CH
Direct distance between the dorsal origin of caudal fin and the posterior insertion of anal fin	DDCPA
Direct distance between the ventral origin of caudal fin and the posterior insertion of anal fin	DVCPA
Direct distance between the anterior insertion of the anal fin and the posterior insertion of anal fin	DAAPA
Direct distance between the anterior insertion of the ventral fin and the anterior insertion of the anal fin	DAVAA
Direct distance between the anterior insertion of the anal fin and the anterior insertion of the pectoral fin	DAVAP
Direct distance between the anterior insertion of the pectoral fin and the posterior end of maxillary	DAPPM

Ls, DALAP/Ls, DALMO/Ls, DADAV/Ls, and CH/Ls were significantly greater for the striped shiner than the slender shiner ($P < 0.01$), whereas the opposite was found for the values of DPDPL/Ls and DPLPA/Ls. We found no significant difference between the values of DALPM/Ls between the two shiner species.

Some of the measured classical dimension were common to both the rockfish and shiners, (DALPS, DALAD, DALMO, DALAV, DALAA, and CH; Tables 1 and 2; Figs. 1a and 2a). As shown in Tables 3 and 4, the value of DALMO/Ls was significantly greater for the rockfish than the shiner, whereas the opposite was found for the values of DALAD/Ls and DALAV/Ls. Thus, the length from the lip to the opecular cover was longer in rockfish than in shiner, and the lengths from the lip to the dorsal and ventral fins were longer in shiner than in rockfish (Figs 3 and 4). These results show that the body length relative to the head region is greater in shiners than rockfish. Classical dimensions have commonly been assessed in studies of the morphometric characteristics of fish bodies. These dimensions are focused on characteristics of the body length, depth, and width, and are mainly studied with respect to the anterior–posterior axis of the body, including the tail and head regions (Straüss & Bond, 1990; Park et al., 2001a, 2004, 2007).

The DALPS/Ls and CH measurements were common to both the classical and truss dimensions, and their values for dark banded rockfish were greater than for black rockfish ($P < 0.05$; Table 3). As the CH/Ls (caudal peduncle height) value for the dark banded rockfish is greater than that for the black rockfish, the upper side of the black rockfish from the dorsal fin to the caudal fin is curved slightly down (Fig. 3), while in the dark banded rockfish it is almost a straight line. The ED/Ls (head) value was greater (12.4%) for the dark banded rockfish than for the black rockfish (9.3%) ($P < 0.05$). The DALMO/Ls and DPSMO/Ls values for the head in the dark banded rockfish (35.1% and 17.4%, respectively) were less than for the black rockfish (36.5% and 18.4%, respectively) (Tables 2 and 3) ($P < 0.05$). These results show that size of the eye as a function of head size is large in the dark banded rockfish relative to the black rockfish.

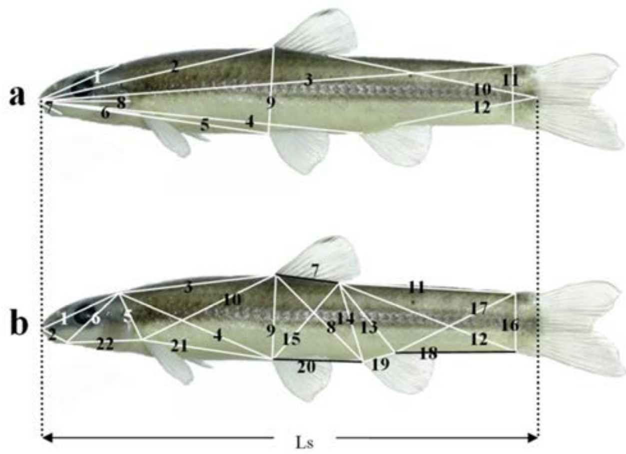

Fig. 2. Truss and classical dimensions measured for the striped shiner, *Pungtungia herzi* and the slender shiner, *Pseudopungtungia tenuicorpa*. (a) classical dimensions: 1, DALPS; 2, DALAD; 3, DALDC; 4, DALAA; 5, DALAV; 6, DALAP; 7, DALPM; 8, DALMO; 9, DADAV; 10, DPDPL; 11, CH; 12, DPLPA. (b) truss dimensions: 1, DALPS; 2, DALPM; 3, DPSAD; 4, DPSAV; 5, DPSAP; 6, DPSPM; 7, DADPD; 8, DADAA; 9, DADAV; 10, DADAP; 11, DPDDC; 12, DPDVC; 13, DPDPA; 14, DAAPD; 15, DAVPD; 16, CH; 17, DDCPA; 18, DVCPA; 19, DAAPA; 20, DAVAA; 21, DAVAP; 22, DAPPM. Refer to Table 2 for details of the dimensions.

As shown in Table 3, the values of DALMO/Ls (classical dimension) and DPSMO/Ls (truss dimension) were greater for the black rockfish than for the dark banded rockfish ($P < 0.05$). The length from the premaxilla to the end of the opercular of the operculum in the black rockfish was longer than in the dark banded rockfish (Fig. 3). In the shiners the truss and classical dimensions for most of the head and body region, and the caudal peduncle height, were significantly greater for the striped shiner, whereas measurements of the caudal region in relation to the anterior posterior body axis were significantly greater in the slender

Table 3. Means and standard deviations of classical and truss dimensions for the dark banded rockfish, *Sebastes inermis* and the black rockfish, *S. schlegeli*, and the results of an ANOVA-test for differences among groups

Morphometric dimension[a]	Dark banded rockfish	Black rockfish	*t*-test
Classical dimension			
DALPS/Ls	26.5±1.95	21.2±1.73	*
DALAD/Ls	36.8±1.20	33.8±1.00	*
DALMO/Ls	35.1±1.04	36.5±1.03	*
DALPD/Ls	90.9±1.21	87.9±0.89	*
DALBP/Ls	34.5±2.23	35.3±0.76	NS
DALAV/Ls	41.7±0.94	40.6±0.71	*
DALPA/Ls	83.9±1.63	82.7±1.23	*
DALAA/Ls	69.0±1.86	69.5±1.55	NS
CH/Ls	11.6±0.49	9.7±0.39	*
ED/Ls	12.4±0.90	9.3±0.51	*
Truss dimension			
DALPS/Ls	26.5±1.95	21.2±1.73	*
DPSMO/Ls	17.4±1.31	18.3±1.42	*
DADPD/Ls	61.3±4.55	60.2±1.61	NS
DADPA/Ls	58.5±1.57	58.5±1.36	NS
DADAA/Ls	47.8±4.18	49.4±1.18	NS
DAVAA/Ls	30.1±2.08	31.4±1.53	NS
DAVPD/Ls	56.9±1.95	54.0±1.17	*
DAAPA/Ls	18.7±1.31	15.4±1.40	*
DAAPD/Ls	30.9±1.19	26.2±1.02	*
DPDPA/Ls	15.0±0.63	12.9±0.78	*
CH/Ls	11.6±0.49	9.7±0.39	*
ED/Ls	12.4±0.90	9.3±0.51	*

[a] Refer to Table 1 for details of dimensions. Data (means±SD, n = 50) were analyzed using a one-way ANOVA on data arcsine square root transformed. *$P < 0.05$; NS: not significant.

shiner (Fig. 4). Similar to the results of this study, Park et al. (2004) investigated eye traits as head measurements is that clarify width between two eyes/distances between head length or premaxilla and two eyes/morphometrics of head length in catfish (Siluridae).

Katoh & Tokimura (2001) compared measurements among the marbled rockfish, *S. marmoratus*, the red marbled rockfish, *S. tertius*, and the yellow barred red rockfish, *S. albofasciatus*, which are related to the two rockfish used in the present study. For these species the distance between the anterior upper jaw and the base of the dorsal fin differed, but no difference was found for the distance between the start of the base of the dorsal fin and the start of the base of the anal fin. In addition, they reported that the distance between the anterior upper jaw and the start of the base of the dorsal fin was greater in the marbled rockfish than in the red marbled rockfish. We found a similar trend in comparisons between the dark banded rockfish and the black rockfish.

Park et al. (2007) conducted a 12-week starvation experiment in olive flounder, *Paralichthys olivaceus*. In terms of truss dimensions, starvation in this predator resulted in a relative increase in body depth., while in terms of classical dimensions starvation resulted in a decrease in the values of traits related to the anterior–posterior axis of body, and an increase in the value of traits related to the head. Truss dimensions have also been applied to understanding the morphometric characteristics of Chinese minnow, *Rhynchocypris oxycephalus* in relation to starvation and predation. Under these conditions changes occurred in the characteristics of the body, rear body, and tail parts. It can identify whether various feed supply due to habitat difference and constant under head part is used as taxonomic indicators of *Rhynchocypris* sp. at starvation and predation experiment in Chinese minnow, inversely. As these fishes show variable measurements following habitat modification (especially starvation) and changes in nutritional status (such as food supplementation), it is essential to establish which morphometric characteristics in which species do not change as a function of variations in feed and environmental conditions (Park et al., 2001a, 2002, 2007).

Of those measurements for which the values were greater in the dark banded rockfish than in the black rockfish, the truss dimensions DAVPD/Ls, DAAPA/Ls, DAAPD/Ls, and DPDPA/Ls were largely related to the body depth from the start of the base of the ventral fin to the end of the base of the dorsal fin (Table 3; Fig. 3). The dark banded rockfish did not differ significantly from the black rockfish with respect to the measurement from the start of the base of the dorsal fin to the end of the base of dorsal fin of posterior body, the start of the base of the dorsal fin and the end of the base of the dorsal fin, and from the start of the base of the ventral fin to point for the base of the caudal fin, as there were no significant differrences in truss dimensions between the dark banded rockfish and the black rockfish for the values of DADPD/Ls, DADPA/Ls, DADAA/Ls, and DAVAA/Ls ($P > 0.05$) (Table 3; Fig. 3).

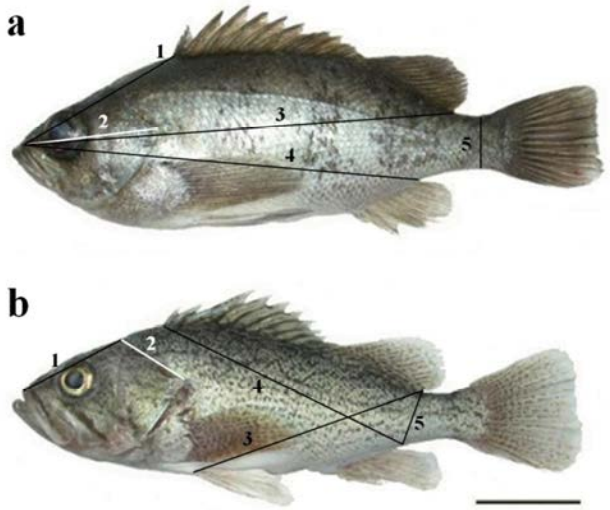

Fig. 3. External morphology of (a) the dark banded rockfish, *Sebastes inermis* and (b) the black rockfish, *S. schlegeli*. Lines of each picture are classical dimension and truss dimension having significantly difference ($P < 0.05$). (a) classical dimension: 1, DALAD; 2, DALMO; 3, DALPD; 4, DALPA; 5, CH. (b) truss dimension: 1, DALPS; 2, DPSMO; 3, DAVPD; 4, DAAPD; 5, DPDPA. Black line: dark banded rockfish > black rockfish; White line: dark banded rockfish < black rockfish. Scale bar is 2 cm.

The truss dimensions for the two shiner species are shown in Table 4. Amongst these the values of DALPS/Ls, DPSAV/Ls, DPSAP/Ls, DPSPM/Ls, DADAA/Ls, DADAV/Ls, DADAP/Ls, DPDPA/Ls, DAAPD/Ls, DAVPD/Ls, CH/Ls, DAVAA/Ls, and DAPPM/Ls were significantly greater in the striped shiner than in the slender shiner ($P < 0.01$), the values for DPDDC/Ls, DDCPA/Ls, and DVCPA/Ls were significantly greater in the slender shiner ($P < 0.01$), and no significant difference was found between the species for the values of DALPM/Ls, DPSAD/Ls, DADPD/Ls, DPDVC/Ls, DAAPA/Ls, and DAVAP/Ls.

Comparing morphometric characteristics between dark

Table 4. Classical and truss dimensions for the striped shiner, *Pungtungia herzi* and the slender shiner, *Pseudopungtungia tenuicorpa*

Morphometric dimension[a]	Striped shiner	Slender shiner	*t*-test
	Classical dimension		
DALPS/Ls	23.1±0.04	19.2±0.02	*
DALAD/Ls	52.2±0.01	47.4±0.01	*
DALDC/Ls	98.4±0.02	94.9±0.03	*
DALAA/Ls	71.8±0.02	61.6±0.07	*
DALAV/Ls	50.7±0.01	46.2±0.01	*
DALAP/Ls	25.4±0.02	21.9±0.01	*
DALPM/Ls	5.3±0.01	5.4±0.01	NS
DALMO/Ls	25.3±0.02	20.2±0.02	*
DADAV/Ls	22.8±0.01	16.9±0.01	*
DPDPL/Ls	38.2±0.02	41.9±0.03	*
CH/Ls	13.0±0.01	11.3±0.01	*
DPLPA/Ls	23.3±0.01	28.0±0.04	*
	Truss dimension		
DALPS/Ls	23.1±0.01	19.2±0.02	*
DALPM/Ls	5.3±0.01	5.4±0.01	NS
DPSAD/Ls	31.3±0.01	31.2±0.02	NS
DPSAV/Ls	34.9±0.01	31.8±0.02	*
DPSAP/Ls	13.4±0.01	10.9±0.02	*
DPSPM/Ls	18.6±0.01	15.8±0.03	*
DADPD/Ls	13.0±0.01	12.6±0.01	NS
DADAA/Ls	29.6±0.01	24.9±0.01	*
DADAV/Ls	22.8±0.01	16.9±0.01	*
DADAP/Ls	30.6±0.01	28.9±0.02	*
DPDDC/Ls	34.0±0.01	38.2±0.04	*
DPDVC/Ls	36.7±0.01	38.1±0.03	NS
DPDPA/Ls	22.0±0.01	19.0±0.01	*
DAAPD/Ls	19.8±0.01	16.2±0.00	*
DAVPD/Ls	23.1±0.01	18.7±0.01	*
CH/Ls	13.0±0.01	11.3±0.01	*
DDCPA/Ls	23.4±0.01	27.0±0.03	*
DVCPA/Ls	18.7±0.02	24.1±0.02	*
DAAPA/Ls	6.2±0.01	6.1±0.01	NS
DAVAA/Ls	21.5±0.02	18.0±0.01	*
DAVAP/Ls	25.5±0.01	25.1±0.02	NS
DAPPM/Ls	20.6±0.01	17.1±0.02	*

[a] See Table 1 for details of dimensions. Data (means±SD, $n = 50$) were analyzed using a one-way ANOVA on data arcsine square root transformed. *$P < 0.01$; NS: not significant.

banded rockfish and black rockfish, the classical dimensions DALAD, DALPD, DALPA and CH of dark banded rockfish were higher than those of black rockfish, and DALMO of dark banded rockfish was lower than black rockfish (Table 3 and Fig. 3a). The truss dimensions DALPS, DAVPD, DAAPD and DPDPA of dark banded rockfish were higher than black rockfish, and DPSMO of dark banded rockfish was lower than black rockfish (Table 3 and Fig. 3b). Comparing morphometric characteristics between striped shiner and slender shiner, the classical dimensions DALPS, DALAD and DALAA of striped shiner were higher than those of slender shiner, and DPDPL and DPLPA of striped shiner was lower than slender shiner (Table 4 and Fig. 4a). The truss dimensions DPSAV, DPSAP and DAVPD of striped shiner were higher than slender shiner, and DPDDC, DDCPA and DVCPA of striped shiner was lower than slender shiner (Table 4 and Fig. 4b).

The truss dimensions DALPS, PADPD, DADAA, DAVAA, DAVPD, DAAPA, DAAPD, DPDPA and CH were common to all species in the study (Tables 1 and 2; Figs. 1 and 2). As shown in Tables 3 and 4, the truss measurements DADPD/Ls, DADAA/Ls, DAVAA/Ls, DAVPD/Ls, DAAPA/Ls, and DAAPD/Ls were significantly greater in the rockfish than in the shiner, whereas the DPDPA/Ls value was significantly greater in the shiner than the rockfish. Thus, the lengths between the dorsal fins, from the dorsal fin to the ventral and anal fins, between the anal fins, and from the ventral to the anal fin were longer in the rockfish than in the shiner, whereas the vertical length of the tail region was longer in the shiner than in the rockfish (Figs. 3 and 4). These results indicate that shiners have an almost straight body line from head to tail, but rockfish have a relatively curved body shape. In addition, the rockfish generally had greater truss dimension values compared with the shiner (Tables 3 and 4), indicating that the body depth is greater in rockfish than in shiners.

Park et al. (2004) reported that for three truss dimensions

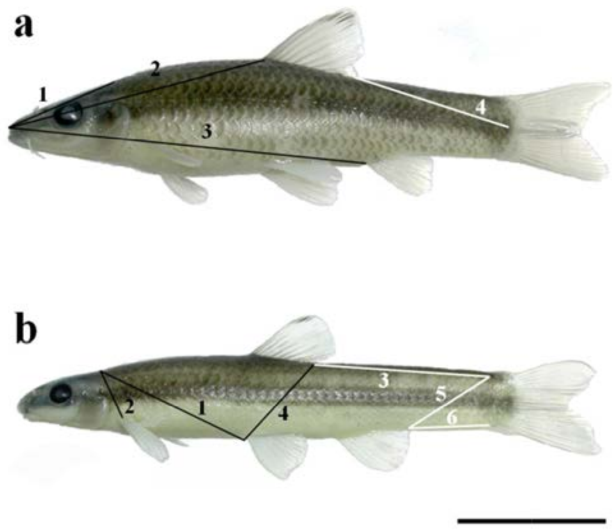

Fig. 4. External morphology of (a) the striped shiner, *Pungtungia herzi* and (b) the slender shiner, *Pseudopungtungia tenuicorpa*. Lines of each picture are classical dimension (a) and truss dimension (b) having significantly difference ($P < 0.05$). (a) classical dimension: 1, DALPS; 2, DALAD; 3, DALAA; 4, DPDPL; 5, DPLPA. (b) truss dimension: 1, DPSAV; 2, DPSAP; 3, DPDDC; 4, DAVPD; 5, DDCPA; 6, DVCPA. Black line: striped shiner > slender shiner; White line: slender shiner < striped shiner. Scale bar is 2 cm.

the slender catfish, *Silurus microdorsalis* had greater values than the far eastern catfish, *S. asotus*. Park et al. (2006c) reported a similar finding for comparison of the bull-head torrent catfish, *Liobagrus obesus* and the Korean torrent catfish, *L. andersoni* with the yellow catfish, *L. mediadiposalis*. They suggested that truss dimensions are appropriate taxonomic indicators for discriminating among species of the Siluridae and the Amblycipitidae.

For more than 30 years, most morphometric investigations of fish have based character selection on the classical dimensions of length, depth, and width, primarily in the head and tail regions (Hubbs & Lagler, 1947). These dimensions are concentrated along the anterior–posterior body axis and in the head–caudal regions, producing an uneven and biased coverage of the entire body form (Li et al., 1993). To describe the shape of a fish using a uniform network of distance measures, Humphries et al. (1981) suggested a criss-cross pattern along the body form, termed the truss dimensions.

In a comparison of rockfish, shiner and catfish, the anal fin and caudal peduncle height of striped shiner were greatest than the other species, but the ED of slender catfish and the head region of slender shiner were smallest (Park et al., 2004). In addition, the lengths between the lip and the dorsal fin, and between the lip and the ventral fin were significantly smaller in catfish relative to the other species, particularly shiner. Our results also indicate that certain truss or classical dimensions may be useful as taxonomic indicators for discriminating among species of rockfish and shiner. Furthermore, comparison with other species may be useful when similarities and differences are evident. In addition, caudal region dimensions (and some truss and classical dimensions that have been used as taxonomic indicators and in relation to embryology, ecology and physiology in salmonid fry, Chinese minnow and Far Eastern catfish, respectively) may also prove useful in discriminating among species of rockfish and shiner (Currens et al., 1989; Park et al., 2001a, 2004). Our findings illustrate that this set of truss dimensions facilitates the detection of differences in shape in oblique, longitudinal and vertical directions, as noted by Straüss & Bond (1990).

The configuration of landmarks reconstructed from measured distances that result in no loss of information has advantages over the use of classical morphometric characters in discriminating in rockfish and shiner. Our results indicate that the use of the truss network as a character set enforces representative coverage across the body form, enhancing discrimination among species.

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