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Geographical variation in morphology of bottlenose dolphins (*Tursiops sp.*) in Chinese waters

Anli Gao, Kaiya Zhou and Yaming Wang

Department of Biology, Nanjing Normal University, Nanjing 210097, P.R. China

Abstract

Sixty three bottlenose dolphins (*Tursiops sp.*) from Chinese waters were examined in the study and 34 were aged. The adults of the northern form were much larger than that of the southern form in body size. After the effect of body length was removed in the covariance analysis, the beak, flipper and dorsal fin were relatively larger in the southern form than those in the northern form. In the cranial measurements, covariance analysis with condylobasal length as covariate demonstrated that 8 length measurements were smaller, while 9 width/height measurements were larger in the northern form than those in the southern. It may greatly result from the elongation of the beak or rostrum of the skull. The southern form had more teeth than the northern, and the northern form had more vertebra than the southern. Because of the large overlap in the external and skeletal characters, we could not find a criterion to separate the two forms clearly except the adult body size.

The two forms could be correctly distinguished by stepwise discriminant analysis with a group of external or skull measurements. But we could not separate the two forms by using a few external or skull characters. Although the variation between the two forms could be demonstrated by factor analysis, it was not great enough to separate the two forms completely. The northern/southern variation in bottlenose dolphin in Chinese waters seemed no larger than that among the three populations of finless porpoise.

The differences between the larger northern and smaller southern forms in Chinese waters was similar to the differences between the larger offshore and smaller inshore forms in South African waters and in the Northwest Atlantic. So far, no data are available regarding the relationship among the Chinese smaller and larger forms and those from other waters. We do not have sufficient evidence to assign the two forms in Chinese waters to two different species.

Introduction

Although a few inshore bottlenose dolphin populations are relatively well studied (Walker, 1981; Ross, 1977; Perrin, 1984; Hersh & Duffield, 1990; Ross & Cockcroft, 1990), there is still insufficient information on the majority of the populations, among them are those in Chinese waters. Distribution of the bottlenose dolphins in Chinese coastal waters and adjacent sea areas has been reported by True (1889), Yang (1964), Wang (1990), Huang *et al.* (1965), Chen *et al.* (1976), Zhou (1965), Zhou *et al.* (1982), and Zhou & Qian (1985). Some differences in body length and skull measurements between the northern and southern forms of the bottlenose dolphin in the China seas have been reported by Zhou (1987). But the variation in morphology between the two forms has not been previously studied statistically. The purpose of the present paper is to present the geographical variation of the bottlenose dolphins in Chinese waters with regard to both external morphology and skeletal measurements.

Material and method

Sixty-three specimens from Chinese waters were available for this study, 46 at our laboratory and 17 at other institutions. External measurements were available for 47 of the specimens and skull measurements for 45. Only skull measurements or external measurements were available for some of the specimens. The identification number, sex, body length, age, locality and description of each specimen used in this study are given in Table 1.

External measurements

Twenty-two out of the 25 external measurements used presented in Table 2, were according to Perrin (1975), but the distance from the center of the eye to center of the blowhole (EYE-BLO) was measured on both left and right sides. Another 3 measurements, projection of lower jaw beyond upper jaw

Table 1. Specimens used in the analysis of external and skull measurement

No.	Sex	Body length (mm)	Age (GLGs)	Form	Locality	Description
1. DMNH 1565	?			N	39°N, 123°6′E	SK[a]
2. DMNH 1566	?			N	39°N, 123°6′E	SK
3. DMNH 3405	?			N	39°N, 123°6′E	SK
4. FDUV 1303	M	2400		N	33°25′N, 122°25′E	EM [b]+SK
5. FUDV 1304	F	2650		N	?	EM+SK
6. FDUV 1670	F	2780		N	30°N, 122°10′E	EM+SK
7. FDUV 46	M			N	31°40′N, 122°10′E	SK
8. NJNU 0025	M		15	S	24°24′N, 118°10′E	SK
9. NJNU 0026	M		7	S	24°24′N, 118°10′E	SK
10. NJNU 0027	M	2340	12	S	23°50′N, 118°150′E	EM+SK
11. NJNU 0028	M	2260	15	S	23°50′N, 118°15′E	EM+SK
12. NJNU 0029	M	2420		S	23°50′N, 118°15′E	EM
13. NJNU 0030	M	2425		S	23°50′N, 118°15′E	EM
14. NJNU 0031	M	2254	10	S	19°15′N, 107°15′E	EM+SK
15. NJNU 0032	M	2162	12	S	19°15′N, 107°15′E	EM+SK
16. NJNU 0033	F	2392	16	S	19°15′N, 107°15′E	EM+SK
17. NJNU 0034	M	3300	18	N	31°N, 122°30′E	EM+SK
18. NJNU 0035	F	2830	7	N	28°45′N, 123°15′E	EM+SK
19. NJNU 0036	F	2130	2	N	30°45′N, 122°50′E	EM+SK
20. NJNU 0037	?		4	N	37°N, 124°15′E	EM+SK
21. NJNU 0038	M		10	N	36°55′N, 123°45′E	EM+SK
22. NJNU 0039	F	3000	25	N	36°55′N, 123°45′E	EM+SK
23. NJNU 0039T	F	1350		N	36°55′N, 123°45′E	EM
24. NJNU 0040T	?		13	S	23°40′N, 117°20′E	SK
25. NJNU 0041	M	1900		N	31°N, 122°30′E	EM
26. NJNU 0041T	F	3120		N	36°55′N, 123°45′E	EM
27. NJNU 0042	M	2300	3	N	31°N, 122°30′E	EM+SK
28. NJNU 0042T	F	2940		N	36°55′N, 123°45′E	EM
29. NJNU 0043	M	3090	15	N	34°30′N, 124°30′E	EM+SK
30. NJNU 0043T	M	2020		N	Yellow S.[c]	EM
31. NJNU 0044	F	2970	18	N	34°30′N, 124°30′E	EM+SK
32. NJNU 0044	?	1330		N	Yellow S.	EM
33. NJNU 0045	M	2990	11	N	34°30′N, 124°30′E	EM+SK
34. NJNU 0046	?		8	N	34°30′N, 124°30′E	SK
35. NJNU 0047	M	2750	5	N	30°45′N, 123°25′E	EM+SK
36. NJNU 0048	M	2260	1	N	30°25′N, 121°E	EM+SK
37. NJNU 0049	M	1515		N	30°45′N, 123°15′E	EM
38. NJNU 0050	F	2850	17	N	31°N, 122°30′E	EM+SK
39. NJNU 0051	F	2700	7	N	31°N, 122°30′E	EM+SK
40. NJNU 0052	M	3120	14	N	31°N, 122°30′E	EM+SK
41. NJNU 0053	F	2880	18	N	31°N, 122°30′E	EM+SK
42. NJNU 0054	F	2685	36	N	31°N, 122°30′E	EM
43. NJNU 0055	F	1310		N	31°N, 122°30′E	EM
44. NJNU 0056	F	2845	9	N	31°N, 122°30′E	EM+SK
45. NJNU 0230	?		5	N	31°N, 122°30′E	SK
46. NJNU 0231	M	2430	9	S	23°40′N, 117°20′E	EM+SK
47. NJNU 0232	F	2540	7	S	23°40′N, 117°20′E	EM+SK
48. NJNU 0233	M	2510	7	S	23°40′N, 117°20′E	EM
49. NJNU 0234	M	2580	6	S	23°40′N, 117°20′E	EM
50. NJNU 0235	M	2760		S	23°40′N, 117°20′E	EM
51. NJNU 0236	M	2590		S	23°40′N, 117°20′E	EM
52. NJNU 0237	M	2047	6	S	23°40′N, 117°20′E	EM+SK
53. NJNU 0340	M	2180	5.5	S	23°40′N, 117°20′E	EM+SK
54. SMNH 20828	F	3030		N	30°40′N, 122°20′E	EM
55. SMNH 20963	?	2910		N	30°40′N, 122°20′E	SK

Table 1. (*Continued*)

No.	Sex	Body length (mm)	Age (GLGs)	Form	Locality	Description
56. SMNH 21117	M			N	30°40′N, 122°20′E	SK
57. SMNH 29063	?	2910		N	30°40′N, 122°20′E	EM
58. SMNH 330	?	2275		N	30°40′N, 122°20′E	EM
59. SMNH 05	?			N	39°N, 123°6′E	SK
60. SMNH 620828	F			N	30°40′N, 122°20′E	SK
61. SMNH 720828	M			N	30°40′N, 122°20′E	SK
62. SMNH N04	?			S	20°30′N, 108°30′E	SK
63. SMNH ?	?			N	39°N, 123°6′E	SK

Note: DMNH, Dalian Museum of Natural History; FDUV, Fudan University; NJNU, Nanjing Normal University; SMNH, Shanghai Museum of Natural History.

[a] Skull.

[b] External measurements.

[c] No latitudes recorded.

Table 2. External measurements

Acronym	Character
1. BL	Body length, tip of upper jaw to base of notch in fluke
2. LTP-MEL	Tip of upper jaw to apex of melon
3. LTP-GAP	Tip of upper jaw to angle of gape
4. LTP-BLO	Tip of upper jaw to blowhole along midline
5. LTP-EYE	Tip of upper jaw to center of eye
6. LTP-ERE	Tip of upper jaw to external auditory meatus
7. EYE-BLO,l	Center of eye to center of blowhole, left
8. EYE-BLO,r	Center of eye to center of blowhole, right
9. EYE-ERE	Center of eye to external auditory meatus
10. EYE-GAP	Center of eye to angle of gape
11. LTP-UMB	Tip of upper jaw to midpoint of umbilicus
12. LTP-GEN	Tip of upper jaw to midpoint of genital aperture
13. LTP-ANU	Tip of upper jaw to center of anus
14. LTP-FLI	Tip of upper jaw to anterior insertion of flipper
15. LTP-TDF	Tip of upper jaw to tip of dorsal fin
16. LLJ/UJ	Projection of lower jaw beyond upper jaw
17. LFLIPAN	Length of flipper, anterior insertion to tip
18. LFLIPAX	Length of flipper, axilla to tip
19. WFLIP	Width of flipper, maximum
20. HDORFIN	Height of dorsal fin
21. LDFBA	Length of dorsal fin at base
22. WFLUKE	Width of fluke, tip to tip
23. GIRMAX	Girth, maximum
24. GIRAXIL	Girth, on a transverse plane intersecting axilla
25. GIRANUS	Girth, on a transverse plane intersecting anus

(LLJ-UJ), length of dorsal fin at base (LDFBA) and maximum girth (GIRMAX), were added by the present authors.

Skeletal measurements

Of the 33 skull characters and vertebrate counts presented in Table 3, 28 were following Perrin (1975) and 1 following Zhou *et al.* (1979). Measurements for temporal fossa and tooth row were taken on both left and right sides.

Age determination

Age was calibrated for 34 specimens, 19 males, 11 females and 4 individuals of unknown

Table 3. Skull measurements and vertebrate counts

Acronym	Character	Acronym	Character
1. CBL	Condylobasal length	18. LUPTOROr	Length of upper right tooth row
2. LROST	Length of rostrum	19. LUPTOROl	Length of upper left tooth row
3. WROSTBA	Width of rostrum at base	20. LRAMUS	Length of left ramus
4. WROS60	Width of rostrum at 60 cm	21. HRAMUS	Height of left ramus
5. WROMIDL	Width of rostrum at midlength	22. LSYM	Length of symphysis
6. WROS3/4	Width of rostrum at 3/4 length	23. LLOTOROr	Length of lower right tooth row
7. WPREORB	Preorbital width	24. LLOTOROl	Length of lower left tooth row
8. WPOSORB	Postorbital width	25. NTEEUPL	Number of teeth, upper left
9. WSUPORB	Minimum supraorbital width	26. NTEEUPR	Number of teeth, upper right
10. WZYGOM	Zygomatic width	27. NTEELOL	Number of teeth, lower left
11. WPARIET	Parietal width	28. NTEELOR	Number of teeth, lower right
12. WPMX	Maximum width of premaxillaries	29. NTH	Number of thoracic vertebrae
13. LTEMPr	Length of right temporal fossa	30. NLU	Number of lumbar vertebrae
14. LTEMPl	Length of left temporal fossa	31. NCA	Number of caudal vertebrae
15. HTEMPr	Height of right temporal fossa	32. NVER	Number of total vertebrae
16. HTEMPl	Height of left temporal fossa	33. N2HERIB	Number of 2-headed ribs
17. TRO-EXN	Tip of rostrum to external nares		

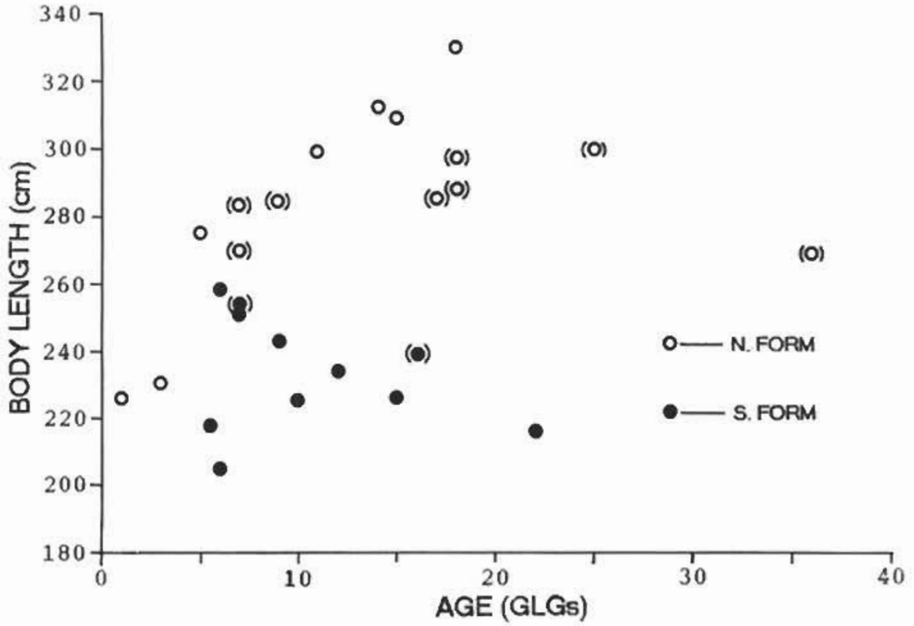

Figure 1. Scatterplots of body length versus age for the northern and southern forms of *Tursiops* in Chinese waters. Parentheses indicate the female specimens.

sex. Body length was available for 27 of these animals.

The age estimates were based primarily on dentinal growth layer groups (GLGs, terminology of Perrin & Myrick, 1980, p. 48), with cemental GLGs as reference. Two or more teeth were collected from the center of the mandibular tooth rows, decalcified in 5–10% nitric acid and 5% formalin for about 2–4 days at room temperature, 5–10°C in winter. Longitudinal buccolingual sections 30 μm thick were cut with an AO 856 Histo Stat freezing microtome at −20°C. Selected sections were examined under a microscope before mounting, to ensure that they were intact and that they passed through the center

Table 4. External measurements (in mm) and meristics for the northern and southern forms of *Tursiops* in Chinese waters

Character	(1) Northern form N	MIN	MAX	MEAN	(2) Southern form N	MIN	MAX	MEAN	Covariance analysis[a]
AGE (GLGs)	16	1	36	12.5	11	5.5	22	10.5	
1. BL	28	1310	3120	2510	15	2047	2760	2392.7	
2. LTP-MEL	20	50	130	99.0	9	115	137	127.0	**1<2
3. LTP-GAP	30	180	355	275.7	9	240	310	275.2	ns
4. LTP-BLO	29	145	435	335.2	9	304	342	323.3	*1<2
5. LTP-EYE	28	220	412	329.1	9	293	358	323.8	ns
6. LTP-ERE	15	265	510	406.5	8	345	424	389.4	ns
7. EYE-BLO,l	17	114	260	199.8	9	152	195	171.8	ns
8. EYE-BLO,r	7	129	260	218.7	9	165	210	185.1	na
9. EYE-ERE	14	45	170	86.1	8	65	84	73.6	ns
10. EYE-GAP	17	41	110	71.7	9	50	67	60.0	ns
11. LTP-UMB	15	600	1500	1206.5	9	925	1173	1052.6	ns
12. LTP-GEN	19	875	2140	1702.6	9	1240	1610	1414.6	na
13. LTP-ANU	20	908	2450	1852.9	9	1410	1810	1623.7	ns
14. LTP-FLI	27	304	680	517.0	9	441	573	513.2	ns
15. LTP-TDF	26	815	1910	1405.8	9	1005	1395	1208.4	ns
16. LLJ-UJ	16	0	40	12.4	9	4	19	11.4	na
17. LFLIPAN	24	239	470	375.3	9	360	416	396.0	**1<2
18. LFLIPAX	26	170	370	275.8	9	280	320	299.1	**1<2
19. WFLIP	24	77	175	137.3	9	130	165	150.4	**1<2
20. HDORFIN	29	129	320	230.7	9	210	269	238.8	*1<2
21. LDFBA	24	215	520	373.0	9	305	500	406.1	**1<2
22. WFLUKE	29	290	780	561.7	9	530	640	592.3	**1<2
23. GIRMAX	15	810	1700	1329.7	9	1100	1250	1172.7	ns
24. GIRAXIL	19	725	1950	1462.9	8	1105	1340	1266.3	ns
25. GIRANUS	14	431	1110	774.9	9	670	820	725.9	ns

Note: See Table 2 for explanation of abbreviations.
[a] with the body length (BL) as covariate.
na, Not analyzed; ns, insignificant; $P>.05$; *$P<.01$; **$P<.001$.

of the tooth. The sections were stained with hemtoxylin, washed, air-dried and mounted in neutral balsam.

The inner GLGs which were deposited at older ages, were thinner and contained fewer sublayers. Age calibration was made along the vertical axis or through the side wall depending on which was clearer. In a very old specimen, NJNU 0054, the inner GLGs after 15th, were composed of only very thin single layers crowding closely.

For each individual, mounted sections were read at least twice. The second scoring was made from another group of slides in the next day, totally independently, in random order and without any reference to body length and previous counts. When the two readings were different, additional sections were prepared, scored and compared with each other, until a consistent scoring was obtained. No specimen with closed pulp cavity was found in our sample, even the specimen with 36 GLGs.

Data Analysis

Multivariate analyses were performed using SPSS statistical software package. Wilks method was employed in the stepwise discriminant analysis. The default selection (F to enter=1.000, F to out=1.000 and Tolerance=0.01) was used in the performance. In the factor analysis, occasional missing measurements for one case was estimated from the nearest specimens with similar body length. Three factors were extracted with Principle Component Analysis, rotated according to the variance maximum for both the external and the skeletal characters, and the factor scores were calculated using Bartlett method.

Results

External proportions

Figure 1 shows the relationship of body length and age in GLGs for both northern and southern

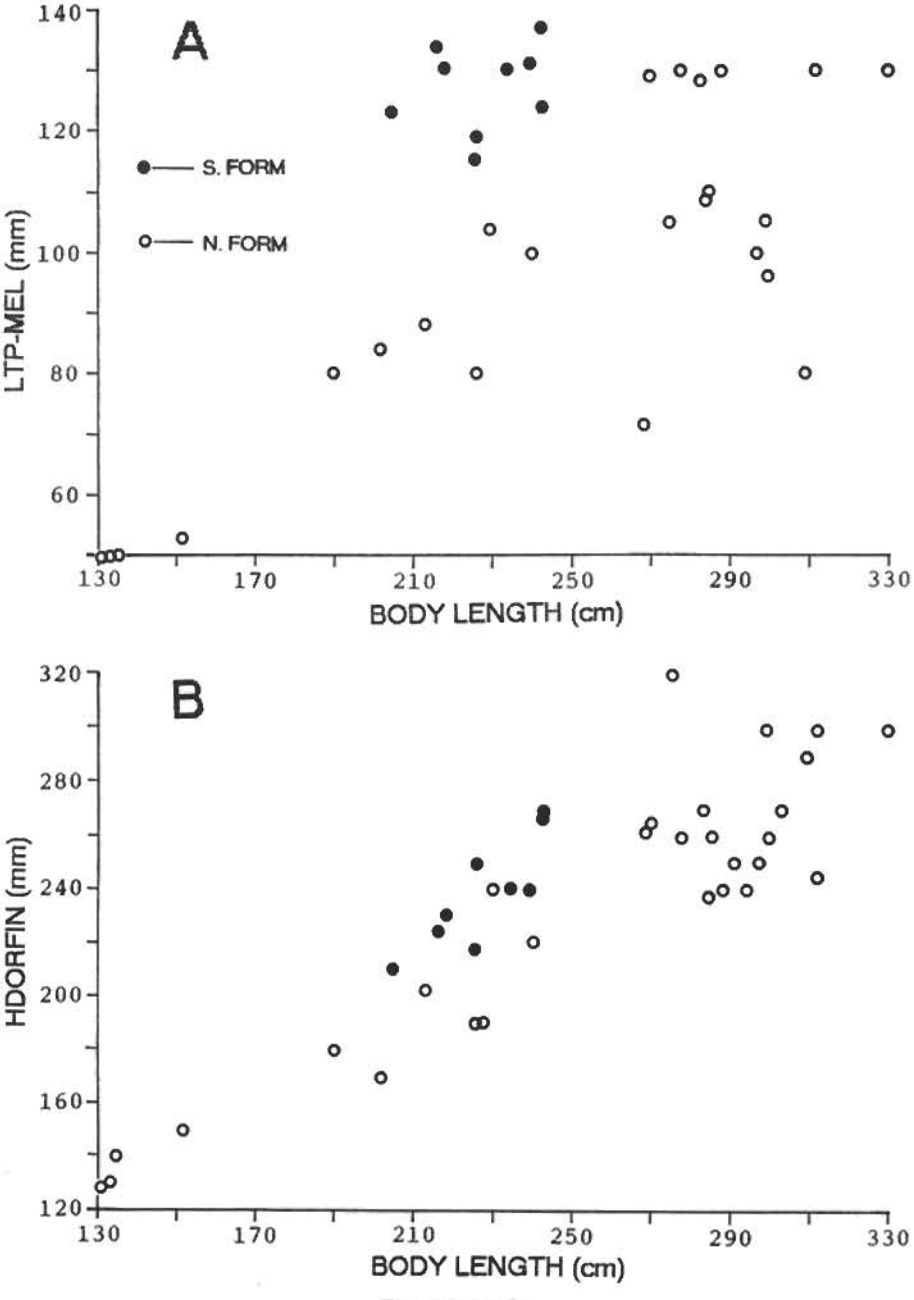

Figure 2. (a)–(b)

forms corresponding to *T. truncatus* and *T. aduncus* respectively in Zhou & Qian (1985). The adults of the northern form were much larger than those of the southern form in overall body size. No overlap was found at the age of 5 or older in the specimens we aged in spite of the fact that one unaged southern specimen (NJNU 0235, BL 2.76 m) was longer than a 7 GLG northern specimen (NJNU 0052, BL 2.70 m). In the northern form, the adult males seemed larger than the females. Data for the southern form (2 females and 9 males) were insufficient for

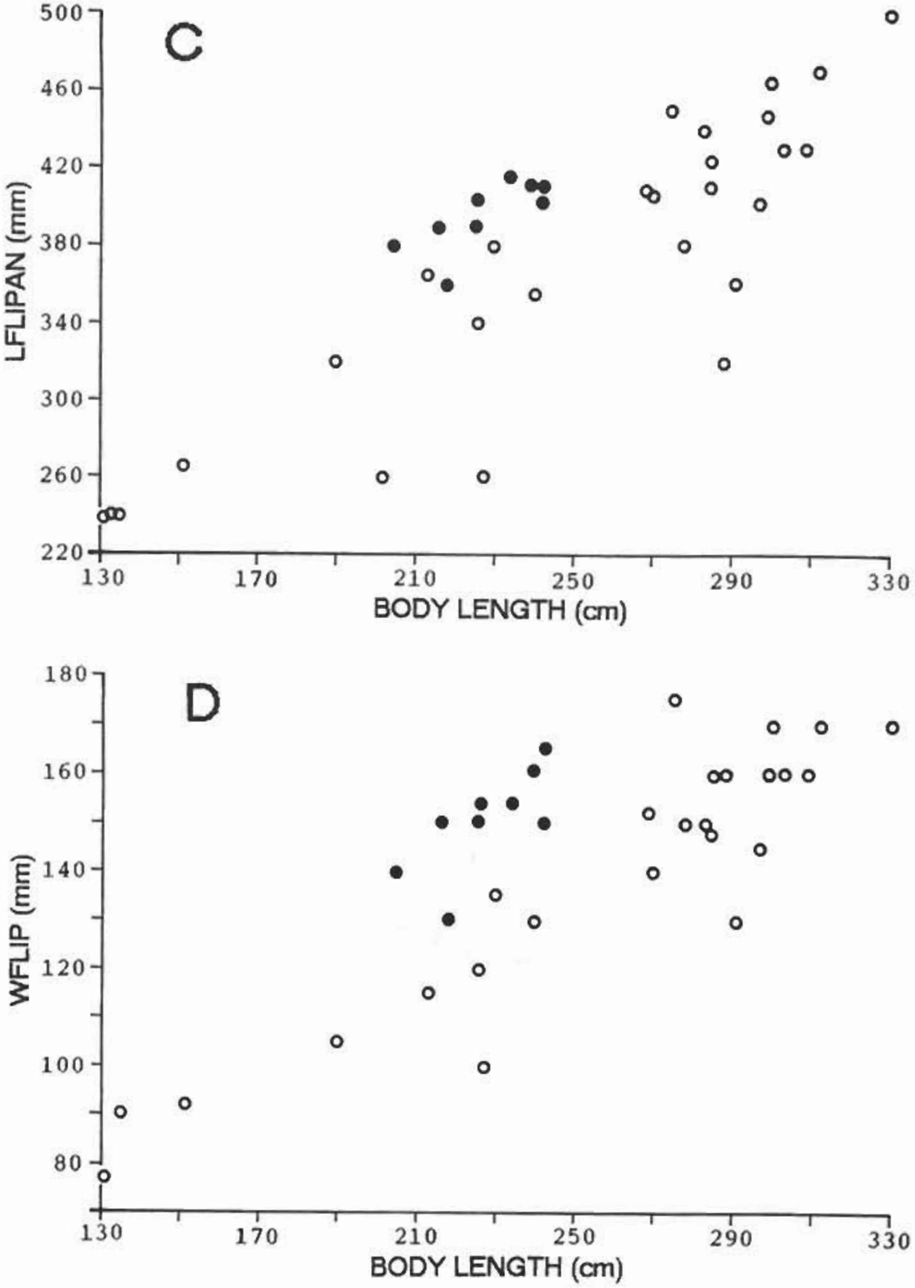

Figure 2. (c)–(d)

Figure 2. Scatterplots of external measurements, A) tip of upper jaw to apex of melon (LTP-MEL), B) Height of dorsal fin (HDORFIN), C) length of flipper, anterior insertion to tip (LFLIPAN) and D) width of flipper (WFLIP) versus body length.

the examination of sexual dimorphism in size (Fig. 1).

Because of the different length structure between the northern and southern forms, covariance analysis was performed to demonstrate the external difference of the two forms. After the variance of body length was removed, 6 of the variables differed between the two forms at the 0.01 level of

Table 5. Statistics for discriminant analysis of external measurements of the northern and southern forms of *Tursiops* in Chinese waters

Character	F-value to enter	Order of entry	Coefficient
1. BL	12.577	4	− 0.007075468
2. LTP-MEL	12.577	1	0.04965687
19. WFLIP	3.0811	3	0.04462625
21. LDFBA	1.7748	6	0.007335223
22. WFLUKE	3.1056	5	0.009028562
4. LTP-BLO	27.955	2	(removed at step 7)
(constant)			− 1.87481

Note: See Table 2 for explanation of abbreviations.

significance and 2 at 0.05 (Table 4). It indicates that the beak, flipper and dorsal fins were relatively larger in the southern form than those in the northern form (Fig. 2a–d).

Both forms were asymmetrical externally in the eye to blowhole measurement. The distance on the left side was less than that on the right. This difference was almost independent of body length.

In the stepwise discrimination analysis (Table 5), all specimens of the two forms could be correctly discriminated (Fig. 3). When the specimens were plotted on the factor functions, the two forms could not be separated completely. Geographical variation was mainly explained by factor 3 (Fig. 4).

Skeleton

The statistical results are presented in Table 6. For the characters which were effected by condylobasal length (CBL), differences between the two forms were analyzed with covariance analysis with CBL as covariate. Among the 23 characters analyzed, 8 differed between the two forms at 0.01 level of significance and 9 at 0.05. They could be classified into two groups. The first is the length measurement, including 8 characters, which were smaller in the northern form than those in the southern (Fig. 5a, b). The second is the width/height measurements, including 9 characters, which were larger in the northern form that in the southern (Fig. 5c, d). For the characters which were not effected by other variables, the t-test was employed. The result suggests that the southern form has more teeth than the northern, and the northern form has more vertebrae than the southern (Table 6).

Only the skull measurements, i.e., the first 24 variances in the skeletal character list, were used in the multivariate analysis. The two forms could be correctly discriminated without overlap (Table 7,

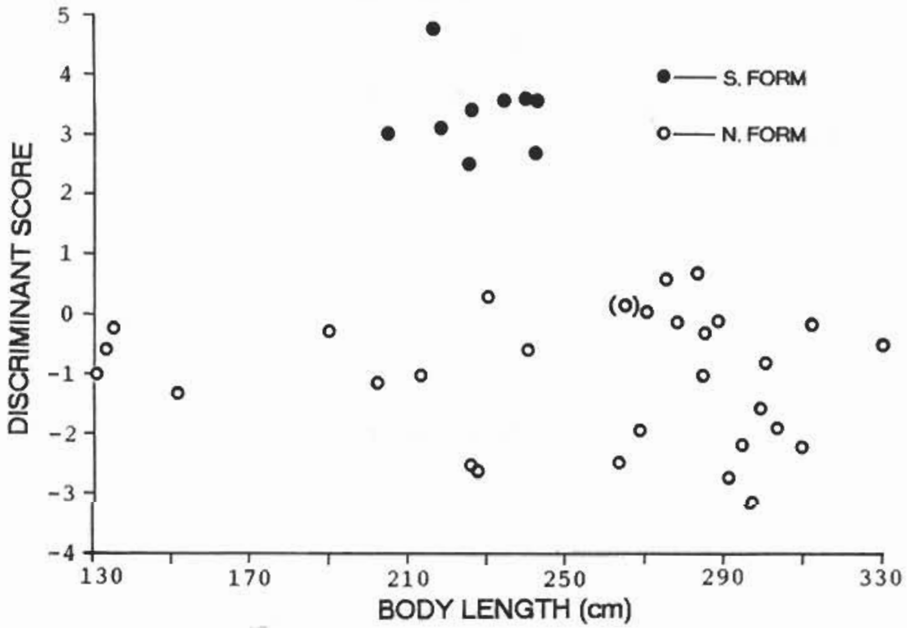

Figure 3. Discriminant scores identified in stepwise discriminant analysis of external measurements of northern and southern forms. Parentheses indicate the specimen, F1304, in Table 1, whose form was determined in this analysis.

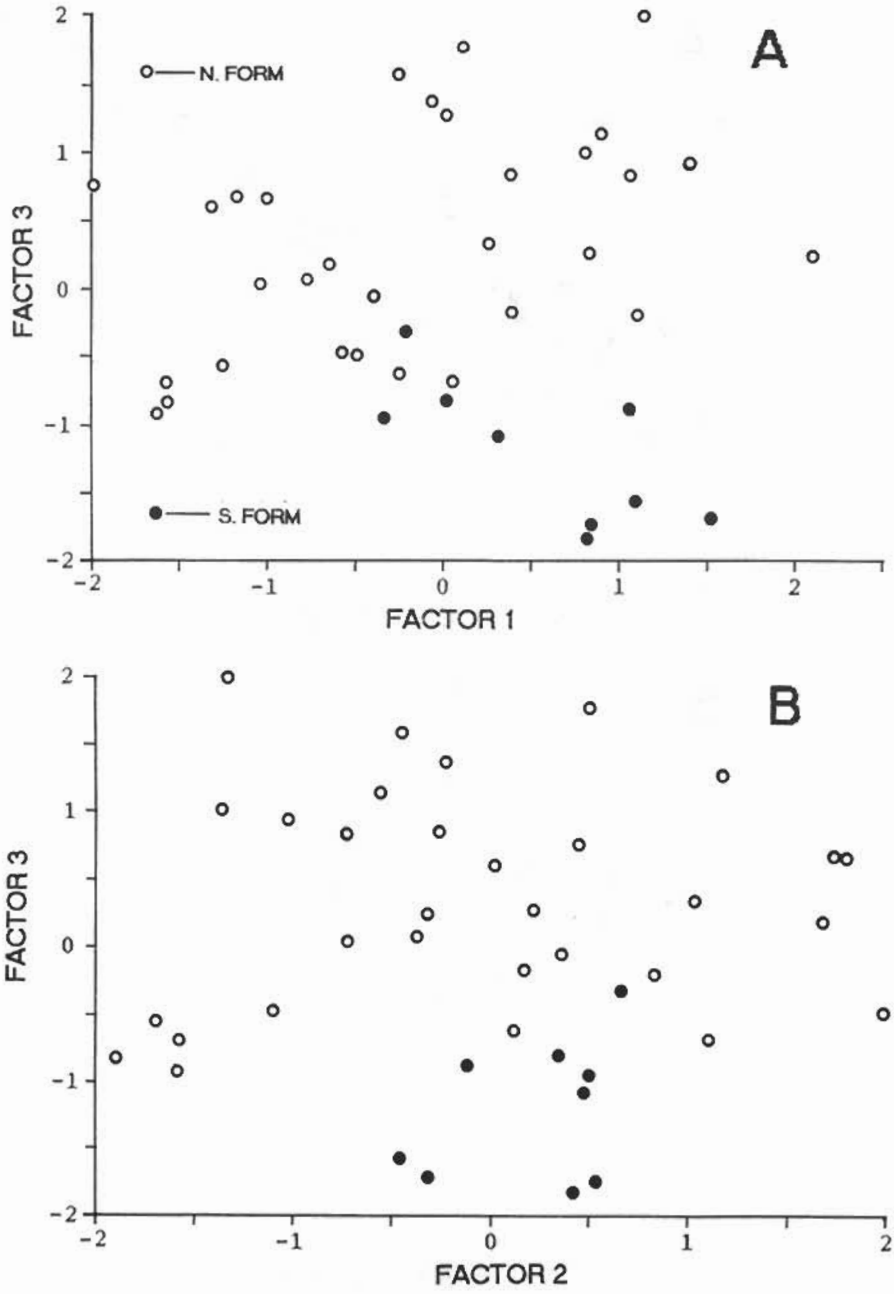

Figure 4. Northern and southern specimens plotted on the factor 1 through factor 3 determined by external measurements.

Fig. 6). When the specimens were plotted on different factors, the two forms were located in different areas with some overlap. Geographical variation was mainly explained by factor 1 (Fig. 7).

Discussion

The northern and southern forms of the bottlenose dolphins in Chinese waters have been referred to *T.*

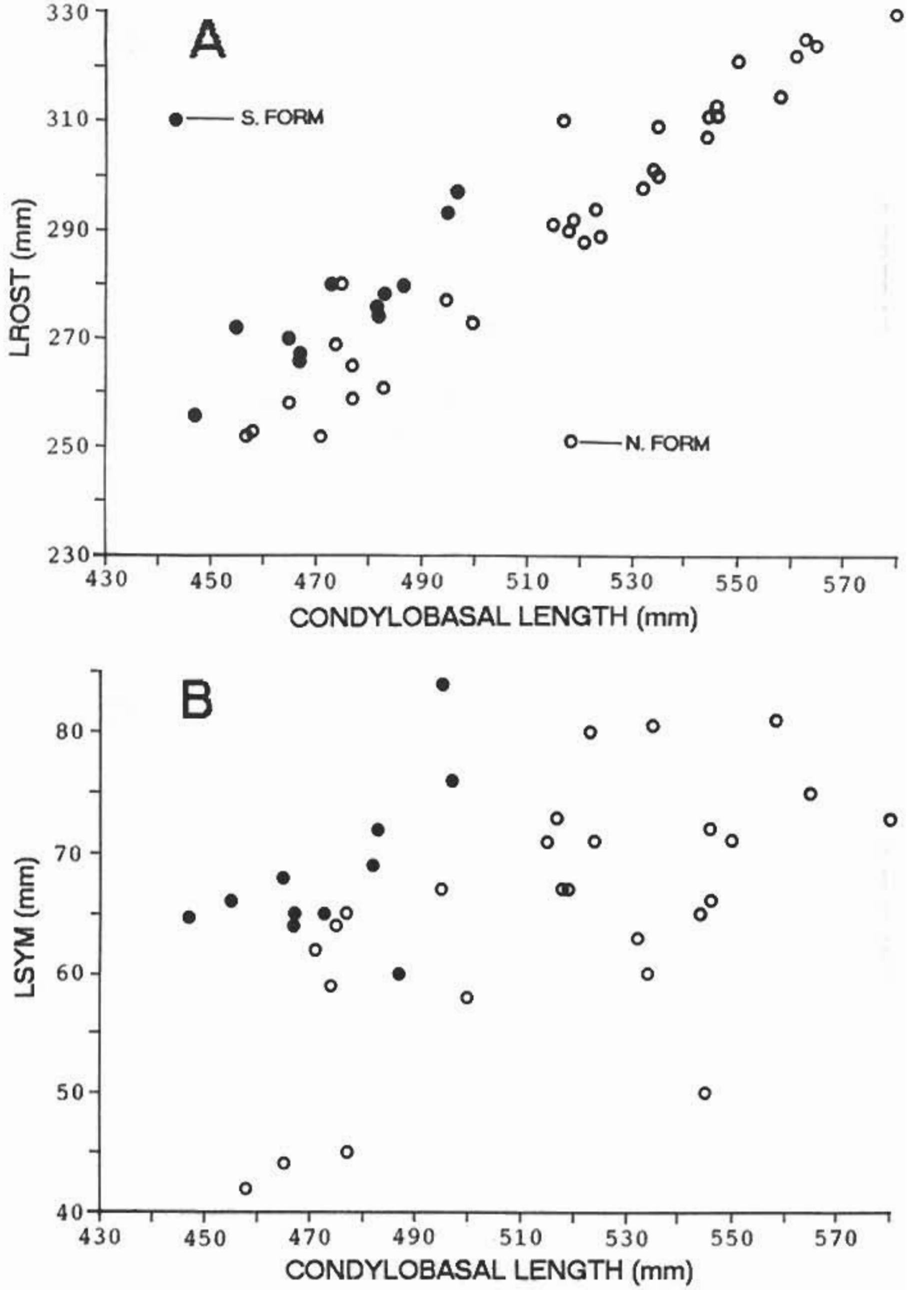

Figure 5. (a)–(b)

truncatus and *T. aduncus* respectively (Zhou, 1987; Zhou & Qian, 1985). According to Zhou (1987), the latter differs from the former in having: longitudinal elongated dark spots on ventral surface between flippers and anus; shorter total body length; relatively longer beak and larger flippers. The skull of the latter is less than 500 mm in CBL and can be distinguished from the former by morphological characters. The total number of vertebrae is 60–61 in the southern form and 64–67 in the northern form. These differences were also recognized statistically in the present study except that the number

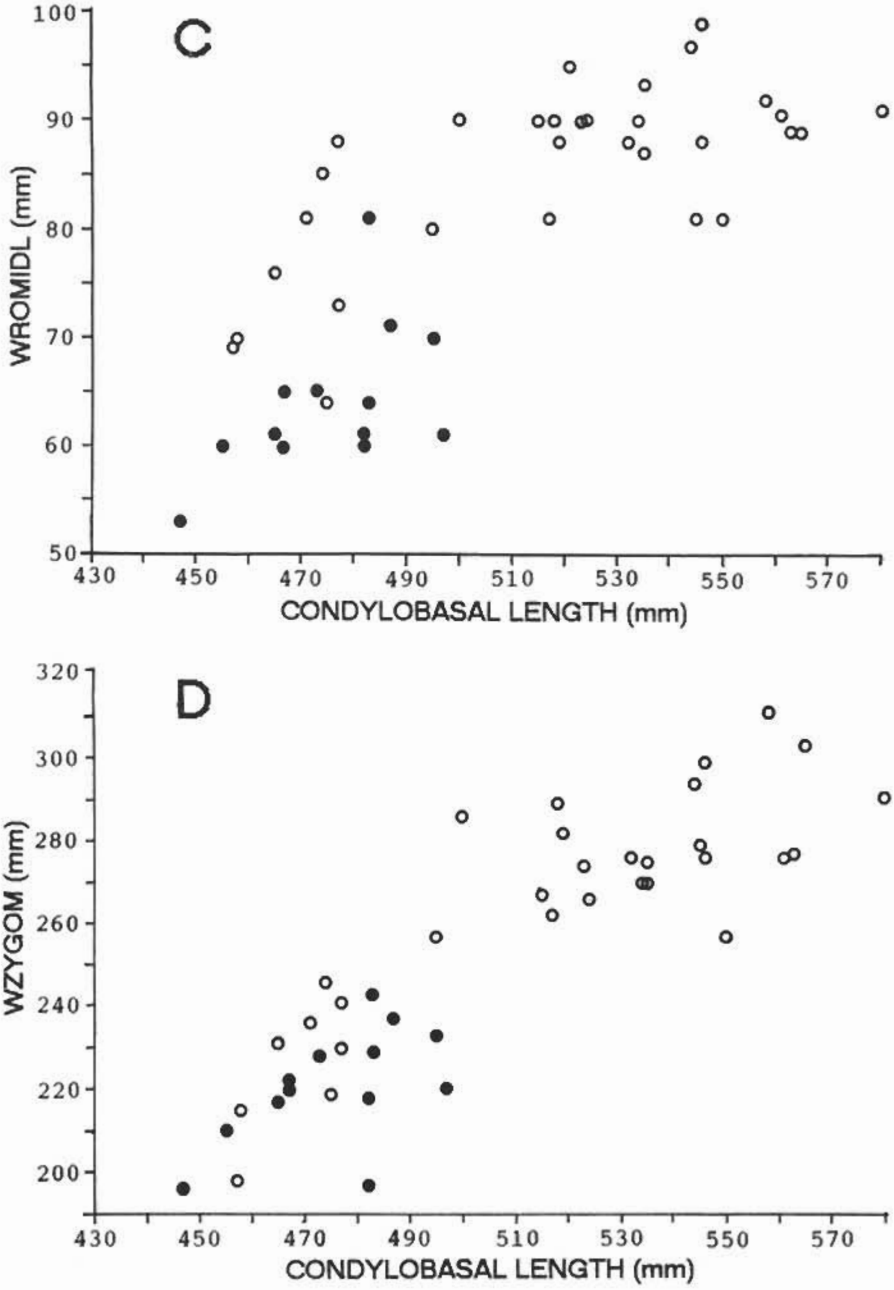

Figure 5. (c)–(d)

Figure 5. Scatterplots of skeletal measurements, A) length of rostrum (LROST), B) length of symphysis (LSYM), C) width of rostrum at midlength (WROMIDL) and D) zygomatic width (WZYGOM) versus condylobasal length.

of the vertebrae overlapped between the two forms (Table 4, 6).

The two forms can be distinguished in adult body length (Fig. 1). And the difference in body size between the two forms seemed greater than that among different populations of the harbour porpoise, *Phocoena phocoena*, in the Baltic (Nielson, 1972), North Sea (van Utrecht, 1978), eastern

Table 6. Skeleton measurements (in mm) and meristics for the northern and southern forms of *Tursiops* in Chinese waters

	(1) N. FORM					(2) S. FORM					
Character	N	MIN	MAX	MEAN	SD	N	MIN	MAX	MEAN	covariance analysis[a]	t-test
AGE (GIGs)	19	1	25	10.4		12	5.5	16	10.6		ns
BL	16	2130	3300	3807.8		9	2047	2540	2289.4		**
1. CBL	32	457	580	517.4	35.31	13	447	497	475.6		**
2. LROST	32	252	330	291.8	24.15	13	255.5	297	274.6	**1<2	
3. WROSTBA	32	108	159	135.4	12.76	13	100.3	128	112.6	*1<2	
4. WROS60	26	76	119	103.1	11.52	13	67.8	92	80.4	**1>2	
5. WROMIDL	32	64	99	85.3	8.47	13	52.9	81	64.0	**1>2	
6. WROS3/4	26	49	81	65.8	7.06	13	39.4	60	49.3	**1>2	
7. WPREORB	24	197	269	238.9	20.04	13	175	225	198.9	*1>2	
8. WPOSORB	25	212	305	262.1	25.99	13	197	241	221.2	*1>2	
9. WSUPORB	31	190	265	230.4	21.60	13	173.4	219	199.3	ns	
10. WZYGOM	31	198	311	264.0	27.73	13	196	243	220.8	*1>2	
11. WPARIET	26	164	204	187.3	9.74	13	163	177	170.8	**1>2	
12. WPMX	29	81	113	96.4	8.32	13	81	90	85.0	ns	
13. LTEMPr	31	85	128	107.3	12.42	10	90	116	100.5	*1<2	
14. LTEMPl	29	83	130	105.3	13.29	13	85	112	97.7	ns	
15. HTEMPr	30	62	92	81.2	8.15	10	67	83	73.4	ns	
16. HTEMPl	29	61	94	79.1	7.83	13	62.7	82	72.3	ns	
17. TRO-EXN	26	292	393	346.8	31.56	13	291	343	320.0	**1<2	
18. LUPTOROr	29	198	285	247.5	22.02	12	214	247	229.4	*1<2	
19. LUPTOROl	29	196	282	246.8	23.05	12	214	248	229.7	**1<2	
20. LRAMUS	28	378	499	442.8	34.28	13	377	433	404.6	ns	
21. HRAMUS	28	79	112	94.6	8.75	13	74.6	90	81.5	*1>2	
22. LSYM	27	42	81	64.3	11.14	13	60	84	68.8	**1<2	
23. LLOTOROr	27	193	274	239.3	22.26	13	212	240	230.0	*1<2	
24. LLOTOROl	27	194	273	239.0	21.34	13	209	241	229.8	*1<2	
25. NTEEUPL	32	18	27	24.0	1.64	13	23	26	24.8		ns
26. NTEEUPR	32	19	27	23.6	1.62	13	24	27	25.1		**
27. NTEELOL	29	21	26	23.1	1.27	13	22	27	24.8		**
28. NTEELOR	29	21	26	23.4	1.18	13	22	27	24.5		**
29. NTH	12	13	14	13.3	0.49	9	12	14	12.6		**
30. NLU	12	15	18	16.5	0.90	9	12	17	14.8		**
31. NCA	11	26	31	28.7	1.62	7	24	19	16.9		*
32. NVER	11	63	67	65.7	1.35	7	59	65	61.0		**
33. N2HERIB	11	5	6	5.5	0.52	7	5	6	5.1		ns

Note: See Table 3 for explanation of abbreviations.
[a]with CBL as covariate.
ns, insignificant $P>.05$; $*P<.01$; $**P<.001$.

North Pacific (Stuart & Morejohn, 1980), eastern Canadian waters (Gaskin *et al.*, 1984) and Japanese waters (Miyazaki *et al.*, 1987), and among the populations of *Neophocaena phocaenoides* in Chinese waters (Gao & Zhou, 1993). For the external measurements analyzed using covariance analysis and t-test (Table 4), only the length of beak was able to consistently separate the two forms in our sample (Fig. 2a). But we are not sure whether it would work for the animals of all ages if we had a larger sample. The length of rostrum overlaps between the two forms (Fig. 5a). The differences demonstrated in skull measurements (Table 6) resulted from the elongation of the rostrum. This made the length measurements relatively larger, and the width/height measurements smaller, in the southern form than those in the northern. Because of the large overlap in the external and skeletal characters, we could not find a criterion to separate the two forms clearly other than the adult body size.

The two forms could be correctly distinguished by discriminant analysis with a group of external or skull measurements (Tables 5 and 7, Figs 3 and 6). But if the number of the variances used in establishing the discriminant function decreased by using larger 'F to enter' and 'F to remove', some specimens would be discriminated incorrectly. The

Table 7. Statistics for discriminant analysis of skulls of the northern and southern forms of *Tursiops*

Character	F-value to enter	Order of entry	Coefficient
5. WROMIDL	36.372	1	0.2715374
22. LSYM	10.635	2	− 0.1290248
13. LTEMPr	4.5979	3	− 0.3410138
1. CBL	7.7443	4	(removed at step 8)
9. WSUPORB	3.2939	5	− 0.1824001
14. LTEMPl	2.1918	6	0.1816811
20. LRAMUS	1.6038	7	0.1794677
16. HTEMPl	2.2590	9	0.2641055
10. WZYGOM	3.3913	10	− 0.1547200
8. WPOSORB	3.9971	11	0.1690774
17. TRO-EXN	4.2367	12	− 0.0633660
15. HTEMPr	1.7343	13	− 0.1001482
	(constant)		− 27.53699

Note: See Table 3 for explanation of abbreviations.

simplest canonical function was 0.07827* (tip of upper jaw to apex of melon) − 0.02259* (tip of upper jaw to blowhole along midline) − 0.5493 for external measurements with the discriminant score criterion at 0.70 resulting in an incorrect discrimination of 1 specimen. The scores of the southern form are larger than those of the northern. And the simplest function was 0.14362 (width of rostrum at midlength) − 0.07857 (length of symphysis) − 6.3005 for the skull specimens with the discriminant score criterion at − 0.65 resulting in an incorrect discrimination of 2 specimens. The scores of the northern form are larger than those of the southern. That is to say, we could not separate the two forms by using a few external or skull characters. Although the variation between the two forms could be expressed by the factor 3 in Figure 4 and factor 1 in Figure 7, it was not great enough to separate the two forms completely.

A study on geographical variation of the finless porpoise in Chinese water using similar methods has shown that different populations could be clearly assigned to different subspecies by the height of dorsal ridge and width of tubercular area (Gao, 1991). The northern/southern variation in bottlenose dolphin in Chinese waters seemed no larger than that among the three populations of finless porpoise.

The bottlenose dolphin is found worldwide in temperate and tropical waters. Several forms have been recognized morphologically in *Tursiops* from different waters. Among them, 3 in the eastern North Pacific (Walker, 1981), 2 in the northwest Atlantic (Hersh & Duffield, 1990), 2 in South African waters (Ross, 1977, 1984) and 1 in Australian coastal waters (Ross & Cockcroft, 1990). The differences between the larger northern and smaller southern forms in Chinese waters was

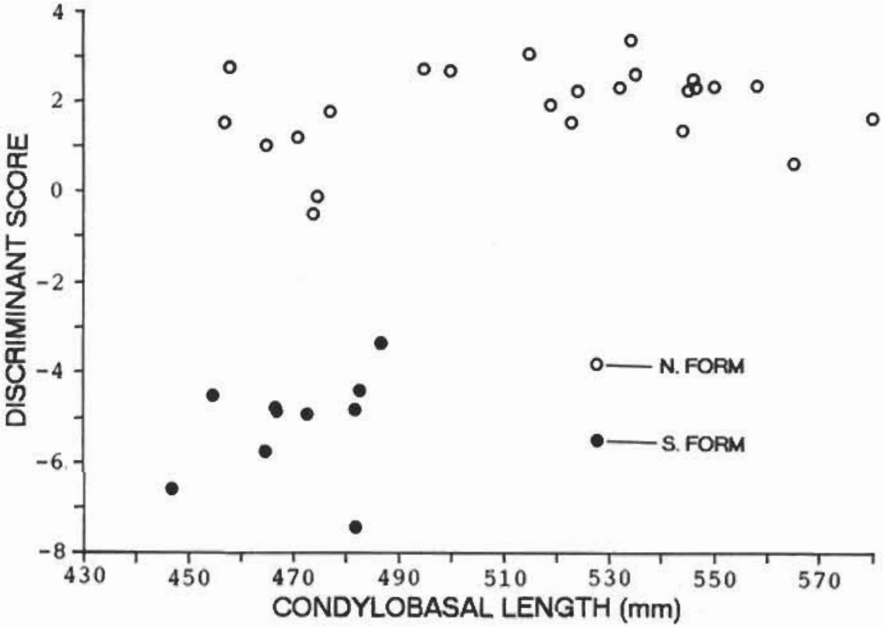

Figure 6. Discriminant scores identified in stepwise discriminant analysis of skull measurements of the northern and southern forms.

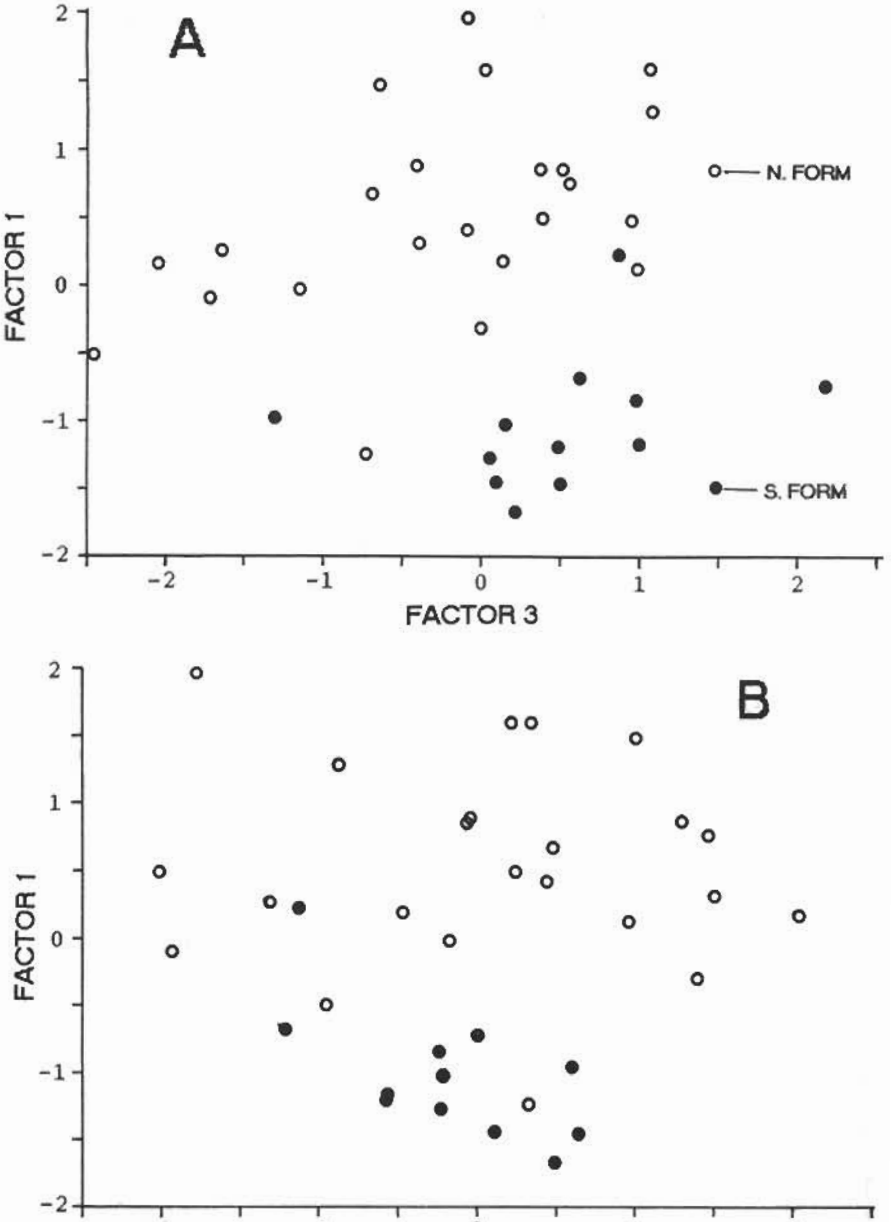

Figure 7. Northern and southern specimens plotted on the factor 1 through factor 3 determined by skull measurements.

much similar to the differences between the larger offshore and smaller inshore forms in the South African waters (Ross, 1977, 1984) and in the Northwest Atlantic (Hersh & Duffield, 1990). So far, no data are available on the relationship, if any, of the Chinese smaller and larger forms and those from other waters. A large sample with good representation from various localities would be helpful in determining if there is any cline among the local and continental forms.

The current international practice is to recognize *Tursiops truncatus* as a single cosmopolitan species.

We do not have sufficient evidence to assign the two forms in Chinese waters to two different species.

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