Japanese Journal of Ichthyology
Vol. 27, No. 2 1980

魚類学雑誌
27巻2号 1980年

Geographic Variation in Vertebral Numbers in Two Pholidid Fishes, *Enedrias nebulosa* and *E. crassispina* around Japan

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(Received March 5, 1980)

Abstract The vertebral variation in *Enedrias nebulosa* and *E. crassispina* (Pholididae) is investigated from 38 sites around Japan. The mean value and range of vertebral numbers are plotted against the latitudes and the mean surface temperatures in December and February. The linear relationships between the vertebral numbers and latitude and temperature show that the vertebral number increases in relation to the higher-latitude and lower-temperature. According to ocean current systems and the response of results comparing numbers to the above two factors and *t*-test between the mean vertebral numbers in samples from all neighbouring sites, populations may be sorted into two major groups, i.e., 1) the Sea of Japan and northern Pacific and 2) the southern Pacific, and a minor Inland Sea group. Vertebral numbers in the Inland Sea group are put between those of the two major groups in each species. The two major groups are considered to represent geographic dimorphism in *Dictyosoma burgeri* and *Pterogobius elapoides*.

The monophyletic genus *Enedrias* Jordan et Gilbert (Pholididae, Blennioidei) is confined to Japan and its adjacent waters. It contains three species, *E. nebulosa* (Temminck et Schlegel), *E. crassispina* (Temminck et Schlegel), and *E. fangi* Wang et Wang, each of which are known from Japan, Japan and Po-hai (northwestern part of Yellow Sea), and Yellow Sea and Po-hai (Yatsu, in press). Previous confusion of *E. crassispina* with *E. nebulosa* since Jordan and Snyder (1902) may be partly caused from great geographic variations in some meristic characters in the two species. The meristic characters in fish are affected considerably by physical and chemical environmental factors (especially by temperature and salinity) (Itazawa, 1957) and possibly by the history of the parents (Dentry and Lindsey, 1978) as well as the genetic background of the populations. I will describe the geographic variation with the view that geographical and ecological distributions of species contribute, or are even indespensable, to the understanding of their history (cf. Hennig, 1966).

Material and methods

A total of 224 specimens of *E. nebulosa* from 21 well-scattered localities and 233 specimens of *E. crassispina* from 27 localities were collected. These specimens are deposited in the following institutions: British Columbia Provincial Museum (BCPM); California Academy of Sciences (CAS); Faculty of Agriculture, Kyoto University (FAKU); School of Fishery Science, Kitasato University (FSKU); Laboratory of Marine Zoology, Hokkaido University (HUMZ); Museum, Tokyo University of Fisheries (MTUF); National Science Museum, Tokyo (NSMT); Ocean Research Institute, University of Tokyo; Rijksmuseum van Natuurlijke Historie, Leiden (RMNH); Yokosuka City Museum (YCM); University Museum, University of Tokyo (ZUMT). Vertebral counts were taken from x-ray negative films. The mean surface temperatures were derived from the atlas by the Japan Oceanographic Data Center (1978). Since the spawning period of *E. nebulosa* in Tokyo Bay is December to January (personal observations) and larvae (10~12 mm TL) of two "types" of *E. nebulosa* (certainly corresponding to *E. nebulosa* and *E. crassispina*) are collected during mid January to early March near Hakodate (Tokuya and Amaoka, 1980), I conveniently used the mean temperatures from December to February for each collection site, so far as they could be

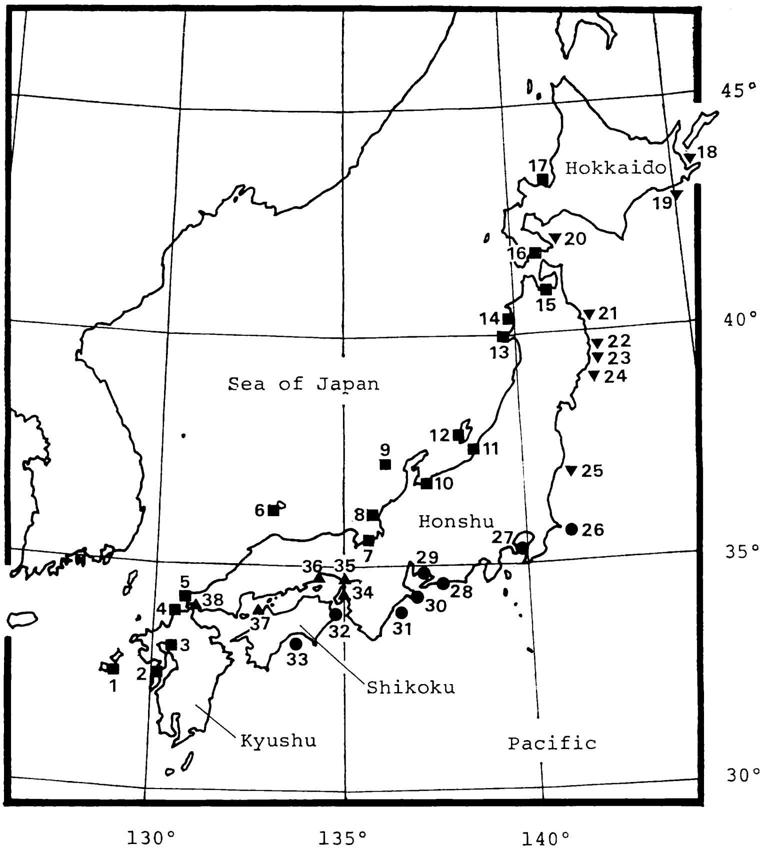

Fig. 1. Collection localities of *Enedrias nebulosa* and *E. crassispina*. Thirty-eight localities are sorted into four areas based on the surface current systems: the Sea of Japan area (represented by ■), northern Pacific area (▼), southern Pacific area (●), and Inland Sea area (▲). Numeral next to each marking corresponds to that of Figs. 2~5 and Tables 1 and 2.

reasonably taken from the atlas. This is a gross approximation based on the atlas that might not hold up to statistical analyses. The salinity, however, is omitted in the present paper due to the nature of spawning habitats of *E. nebulosa*; the eggs are laid on a very shallow or dried-up sea bottom during ebb tide in a small bay (personal observations) and such places are usually affected by considerable inflow of fresh water. Collection sites numbered 1 to 38 are sorted into four geographical areas based on the surface current systems (Uda, 1935): 1) the Sea of Japan area, from the western coast of Kyushu to the western coast of Hokkaido; 2) the northern Pacific area, from the eastern coast of Hokkaido to the Joban Coast; 3) the southern Pacific area, from the Cape Inubo (35.7°N, 140.9°E) to the southern coast of Shikoku; 4) the Inland Sea area (Setonai-kai) (Fig. 1). Longitude and latitude at each site appear in Tables 1 and 2.

Results

Enedrias nebulosa (Table 1): The vertebral mean values and range from the Sea of Japan area and the northern Pacific area have an approximately linear relationship to the latitude (geographical cline). While those from the southern Pacific area seem to be rather constant regardless of the latitude. Those from the Inland Sea are plotted between the above two (Fig. 2). Although data on the Inland Sea area are absent, a similar clinal

Table 1. Precise location, mean surface temperature (°C) in December and in February, number of specimen and vertebral variation of specimens of *Enedrias nebulosa* from 21 sites.

Locality	Lat. (N)	Long. (E)	Mean Temp. Dec.	Mean Temp. Feb.	N	Vertebral Number Range	Vertebral Number Mean	Vertebral Number S.D.
1. Fukue Is.	32.7	128.8	18.5	15.0	19	84~86	84.7	0.65
2. Mogi	32.8	129.9	17.5	14.0	6	83~85	84.0	0.63
3. Sanmon	33.1	130.4	—	—	1	84	84.0	—
6. Oki Is.	36.1	133.1	17.0	12.0	2	83~86	84.5	2.12
7. Maizuru	35.5	135.4	15.5	9.5	12	85~88	86.6	1.08
8. Kanaiwa	36.4	136.4	15.5	9.5	1	87	87.0	—
9. Off Ishikawa	37.2	136.4	16.0	10.0	1	88	88.0	—
10. Toyama Bay	36.7	137.3	15.0	9.5	3	86~87	86.3	0.58
11. Niigata	37.5	138.5	15.0	9.5	10	86~88	87.2	1.23
16. Hakodate	41.8	140.7	13.5	8.5	4	87~88	87.8	0.50
20. Usujiri	41.9	141.0	9.0	5.0	2	88	88.0	—
23. Ozuchi	39.4	141.9	12.5	7.5	1	89	89.0	—
24. Sanriku	39.1	141.8	12.5	7.5	10	86~89	87.9	0.88
26. Choshi	35.7	140.9	15.0	14.0	23	86~90	88.4	0.96
27. Tokyo Bay	35.3	139.7	—	—	62	86~91	88.4	1.11
28. Hamanako	34.7	137.6	17.5	13.0	13	86~90	88.2	1.10
30. Shima	34.4	136.9	18.0	10.0	1	90	90.0	—
31. Owase	34.1	136.3	18.5	16.0	3	89~90	89.3	0.58
33. Tosa Bay	33.4	133.5	20.0	16.0	16	87~90	88.3	0.96
37. Matsuyama	33.9	132.7	—	—	4	86~87	86.5	0.71
38. Karato	34.0	131.0	—	—	26	84~87	85.7	0.87

Table 2. Precise location, mean surface temperature (°C) in December and in February, number of specimen and vertebral variation of specimens of *Enedrias crassispina* from 27 sites.

Locality	Lat. (N)	Long. (E)	Mean Temp. Dec.	Mean Temp. Feb.	N	Vertebral Number Range	Vertebral Number Mean	Vertebral Number S.D.
2. Mogi	32.8	129.9	17.5	14.0	1	86	86.0	—
4. Fukuoka	33.6	130.4	17.0	13.5	1	83	83.0	—
5. Yoshimi	34.1	130.9	17.5	13.5	1	84	84.0	—
7. Maizuru	35.5	135.4	15.5	9.5	12	82~86	84.3	1.06
12. Sado Is.	38.0	138.3	15.0	9.5	11	84~87	85.4	1.07
13. Oga	39.9	139.8	14.5	9.5	2	84	84.0	—
14. Hachimori	40.4	140.0	14.5	9.5	12	81~86	83.8	1.25
15. Asamushi	40.9	140.8	14.0	8.5	4	85~88	86.3	1.26
16. Hakodate	41.8	140.7	13.5	8.5	134	83~89	85.4	1.04
17. Otaru	43.2	141.0	9.5	7.5	15	86~89	87.4	0.80
18. Bekkai	43.4	145.3	6.5	−0.5	1	86	86.0	—
19. Akkeshi	43.0	144.9	6.5	−0.3	1	88	88.0	—
20. Usujiri	41.9	141.0	9.0	5.0	2	86~87	86.5	0.71
21. Taneichi	40.4	141.7	13.0	7.5	6	85~86	86.5	0.83
22. Yamada	39.5	142.0	12.5	7.5	14	84~88	86.6	1.00
23. Ozuchi	39.4	141.9	12.5	7.5	4	86~90	87.5	1.92
24. Sanriku	39.1	141.8	12.5	7.5	8	86~89	87.6	1.30
25. Onahama	36.9	140.9	13.0	10.0	3	84~86	85.3	1.16
27. Tokyo Bay	35.3	139.7	—	—	25	81~83	81.6	0.64
28. Hamanako	34.7	137.6	17.5	13.0	1	81	81.0	—
29. Mikawa Bay	34.8	137.2	—	—	1	80	80.0	—
32. Komatsujima	34.0	134.6	16.0	12.0	1	81	81.0	—
34. Sumoto	34.3	134.9	—	—	1	84	84.0	—
35. Akashi	34.6	135.0	—	—	5	81~83	82.4	0.89
36. Oku	34.6	134.2	—	—	5	82~84	83.2	0.84
37. Matsuyama	33.9	132.7	—	—	2	82~84	83.0	1.41
38. Karato	34.0	131.0	—	—	1	84	84.0	—

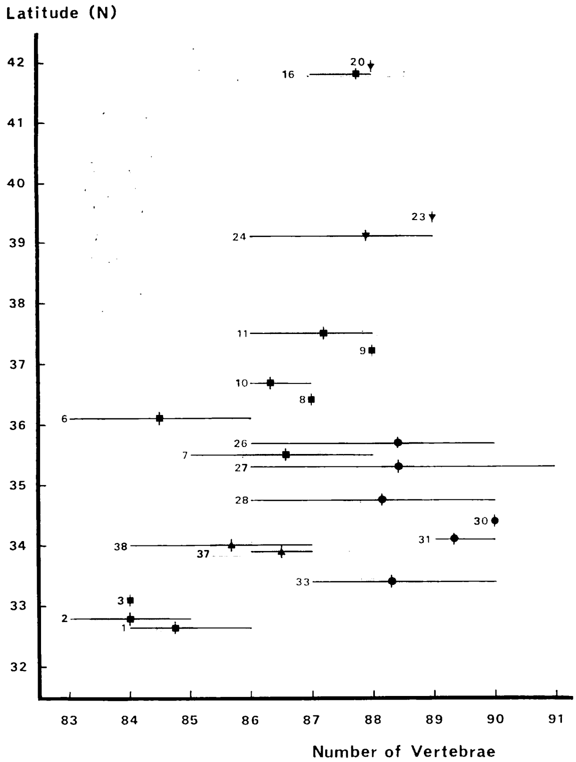

Fig. 2. Vertebral mean value, range, and 95% confidence interval from 21 sites of *Enedrias nebulosa* plotted against the latitude. Mean value, range, and 95% confidence interval (those of small sample-sized sites (two and three specimens) omitted) are represented by: short vertical bar, horizontal line, and hatched area, respectively.

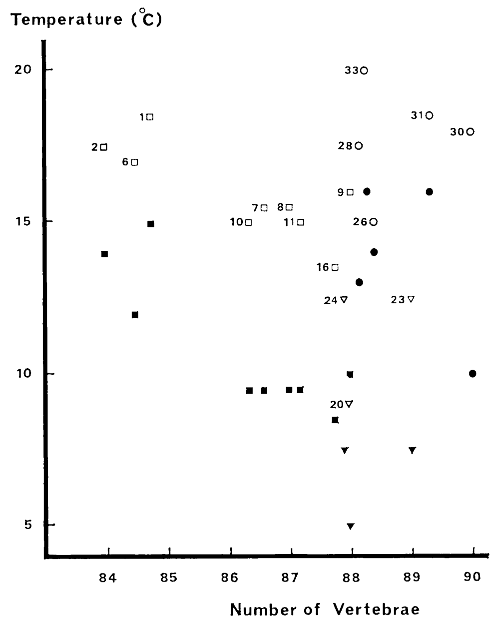

Fig. 3. Vertebral mean value from 17 sites of *Enedrias nebulosa* plotted against the mean surface temperature (°C) in December (solid markings) and in February (hollow markings).

relationship can be found between the mean surface temperature and vertebral mean values and range in both December and February (Fig. 3). It should be noted that localities from the obviously warmer southern Pacific area show higher vertebral numbers than the other sites excepting Ozuchi which is represented by a sole specimen. According to geographical studies and experimental work, the linear relationship between vertebral numbers and latitude and temperature are observed in many fishes, i.e., the lower the temperature becomes the higher are the vertebral numbers (see review by Itazawa, 1957). When we accept this linear relationship in both the Sea of Japan and northern Pacific areas and the southern Pacific area, the regression curves from the two sets of areas are so different from each other that statistical tests are needless.

Enedrias crassispina (Table 2): The vertebral mean values have a linear relationship, as described above, to both the latitude and the mean temperature in gross (Figs. 4 and 5). Vertebral mean values from the Inland Sea area are plotted between those of the Sea of Japan area and southern Pacific area. Here, the relative position of the Inland Sea data compared to the above two areas is reversed contrasting with that of *E. nebulosa* (cf. Fig. 2).

Geographical gaps and discussion

In order to find the geographical gaps in both species, *t*-tests of the vertebral mean values between samples from all neighboring sites were made. Between the following neighboring localities significant differences

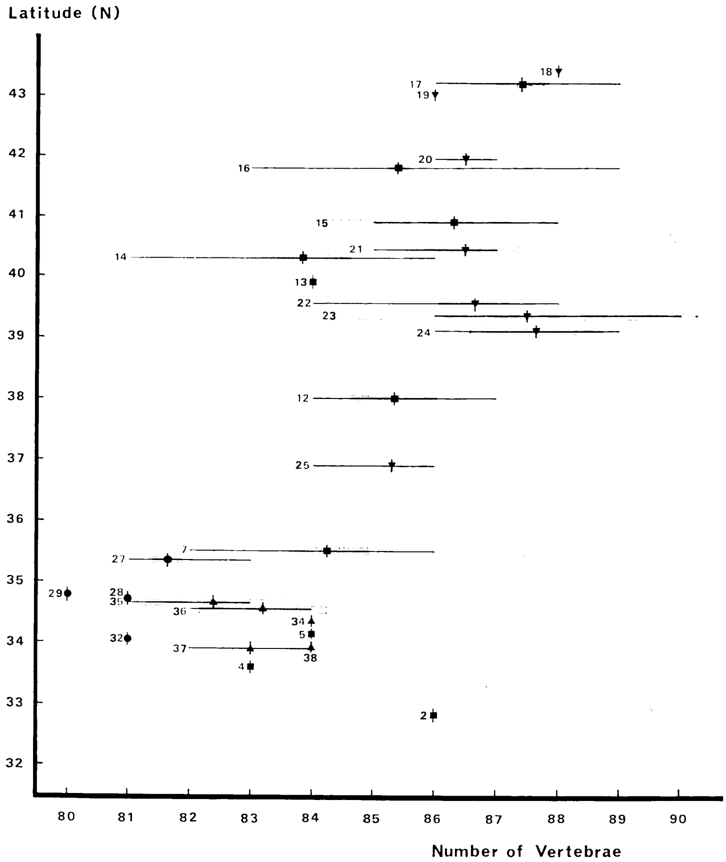

Fig. 4. Vertebral mean value, range, and 95% confidence interval from 27 sites of *Enedrias crassispina* plotted against the latitude. For legends, see Fig. 2.

($P<0.01$) are recognized: *E. nebulosa*, Tosa Bay versus Matsuyama ($t=3.39$, d.f.$=18$) and Fukue ($t=12.59$, d.f.$=33$), Karato versus Mogi ($t=4.41$, d.f.$=30$); *E. crassispina*, Asamushi versus Hachimori ($t=3.30$, d.f.$=13$), Onahama versus Tokyo Bay ($t=8.74$, d.f.$=26$). The mal-distribution in sample size (e.g., small sizes in the southern Pacific area in *E. crassispina*) and rather small sample size as a whole, might have obscured and/or misled the results. For example, we might have mistakenly considered samples from one population as coming from a different one or vice versa.

However, the above geographical gaps do not falsify the present division of collection sites into four areas based on ocean current systems. Some of the gaps correspond to particular boundaries so that it appears that the southern Pacific area and the Sea of Japan and the northern Pacific area are independent from each other and that the Inland Sea populations are influenced genetically by both of the above areas. The independence of the two major areas corresponds to the geographic dimorphism in the lateral line structure and in some meristic characters of *Dictyosoma burgeri* van der Hoeven (Yatsu et al., 1978) and in the coloration of *Pterogobius elapoides* (Günther) (Tanaka, 1931).

Love and Larson (1978) discussed geographic variation in the frequency of occurrence of tympanic cranial spines in *Sebastes atrovirens* (Jordan et Gilbert) with relation to possible gene flow among central and southern California populations. Love and Larson (1978) pointed out that the possibly restricted gene flow may partly be explained by the limited dispersal of larvae due to the currents and eddies in the California waters. Although the

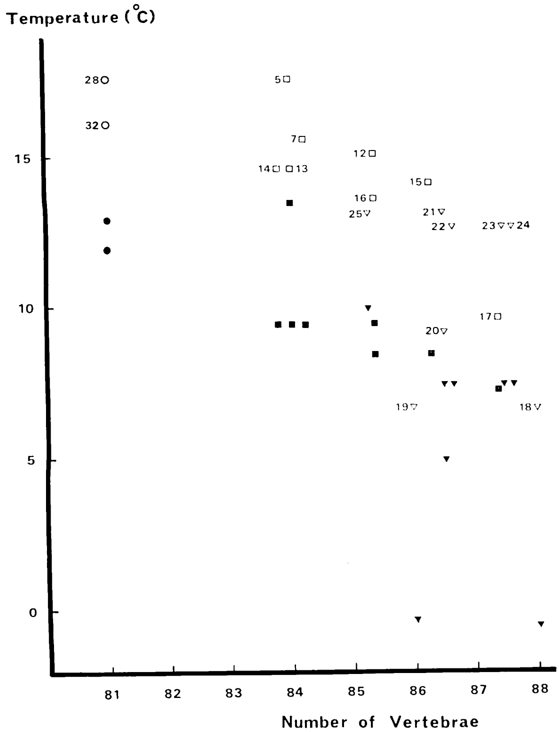

Fig. 5. Vertebral mean value from 18 sites of *Enedrias crassispina* plotted against the mean surface temperature (°C) in December (solid markings) and in February (hollow markings).

larval dispersal in the above Japanese four species are not investigated, the recent currents around Japan match the present results.

Taking into consideration that *Enedrias*, *Dictyosoma*, and *Pterogobius* are all endemic to Japan and its adjacent waters, the common vicariant pattern in the four species may be reasonably attributed to their common history and/or common environmental effects. One possible common historical event can be parsimoniously speculated by the geographic isolation of the Sea of Japan during the most recent (Würm) glaciation as depicted by Nishimura (1977).

Acknowledgments

I wish to express my gratitude to Messers Mitsugu Toyoshima, Kunihiko Tokuya and Kaoru Kido of HUMZ, Mr. Hironori Kudo (Akita), Messers Harumi Sakai, Akihisa Iwata, Keiichi Sakai and Seiichi Hosoya of the Tokyo University of Fisheries, Dr. Yoshie Dotsu of the Nagasaki University and Mr. Noritaka Mochioka of the Hiroshima University for their kind cooperation in collecting and/or supplying the material. I am also grateful to the following persons and institutions for the loan of specimens: Drs. Tamotsu Iwai and Izumi Nakamura (FAKU), Dr. Hitoshi Ida (FSKU), Dr. Takao Igarashi (HUMZ), Dr. Ryoichi Arai (NSMT), Dr. Marinus Boeseman (RMNH), Mr. Masayoshi Hayashi (YCM), Dr. Yoshiaki Tominaga and Mr. Yoh Yamashita (University of Tokyo).

Drs. Fujio Yasuda and Yasuhiko Taki and Mr. Jack T. Moyer read the manuscript critically.

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ニシキギンポ科の2種，ギンポ *Enedrias nebulosa* と *E. crassispina* の脊椎骨数の日本周辺における地理的変異

谷津　明彦

日本周辺の 38 地点から得られたギンポ *Enedrias nebulosa* と *E. crassispina* の脊椎骨数の変異について調査した．脊椎骨数の平均値と範囲を緯度及び 12 月と2月の平均表面水温に対してプロットすると，より北方の，またより低水温の場所からのものがより多数の脊椎骨数を持つという関係が両種で認められた．表層の海流系，上記の2要因に対する脊椎骨数の反応，及び全ての隣接地点間の脊椎骨数の平均値の *t* 検定にもとづけば，38 地点を日本海ー北部太平洋域と南部太平洋域に2大別することが可能と思われる．上記2海域からのグループは，ダイナンギンポとキヌバリの地理的2型と対応している．

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会員への会費の督促状を会計監事名で出すことにした．4. 日本学会事務センターとの契約について検討し，了承した．5. その他．

編集後記・Editorial Notes

本号の会員通信には，本誌で発表された論文についての会員間のディスカッションを掲載しました．このような紙上討論は，それを純粋に科学の範囲にとどめることができる限り，歓迎すべきことと思います．日本魚類学会の会員と魚類学雑誌の科学的レベルはすでにそのような討論を可能ならしめているという自負のもとに，ここに紙上討論第1号を掲載した次第です．　(Y.T.)

訂　正・Errata

魚類学雑誌 27(2)．117 ページ，Table 2, 18 行目の vertebral number "85～86" を 85～87 に，119 ページ，Fig. 4. の positions of site numbers "17 (88, 43.4)" と "19 (86, 43.0)" をそれぞれ 17 (86, 43.4) と 19 (88, 43.0) に訂正．

Japanese Journal of Ichthyology, 27(2). Page 117, Table 2, line 18: range of vertebral number "85～86" should read 85～87. Page 119, Fig. 4: positions of site numbers "17 (88, 43.4)" and "19 (86, 43.0)" should read 17 (86, 43.4) and 19 (88, 43.0), respectively.