Brain-spinal cord ratios in porpoises: Possible correlations with intelligence and ecology¹

SAM H. RIDGWAY, MARINE BIOSCIENCE FACILITY, POINT MUGU, CALIFORNIA
N. J. FLANIGAN, BIOLOGY DEPARTMENT, ST. NORBERT COLLEGE
JAMES G. MCCORMICK, DEPARTMENT OF PSYCHOLOGY, PRINCETON UNIVERSITY

As a rough measure of intelligence, brain weight: cord weight ratios in small delphinids compared favorably with, but were slightly less than, this ratio in man. Not all delphinids studied were found to achieve the minimum 1000 gm brain weight correlate of language development in the human child. The average adult brain size in some small pelagic cetaceans was found to be about 800 gm, while the average for *Tursiops truncatus*, an estuarine species, was found to be about 1450 gm.

The Atlantic bottlenose porpoise (or dolphin) *Tursiops truncatus* has impressed both laymen and scientific investigators as being highly intelligent. McBride & Hebb (1948) considered the problems of assessing intelligence with special reference to *T. truncatus*. They were only able to conclude that with respect to its emotional and motivational characteristics, the bottlenose porpoise lies somewhere between dog and chimpanzee. Kellogg (1961) classified this porpoise's intelligence between dog and man. Recently Morgane (1965) has found that the cytoarchitectural and laminar differentiation patterns in *T. truncatus* brain compare favorably with higher primates, including man. From behavioral, brain weight, and linguistic studies, Lilly (1961) postulates near-human intelligence for this porpoise.

Through comparisons of brain weight with body weight, body length, and body surface in vertebrates generally and for Cetacea in particular, Dubois concluded that man occupies the highest level (7th) of nervous cephalization, anthropoid apes and odontocetes a 5th group and mysticetes the 4th (van der Klaau, 1948). More recently, Wirz (1950) has regrouped these forms based upon measurements confined to the brain. When the brain is divided into olfactory, neopallial, basal ganglial and cerebellar portions and when these weights are then compared with the "remainder" of the brain (roughly equivalent to the lower brain stem), her system places the odontocetes on a par with man, the mysticetes on a par with other primates.

In addition to his speculation concerning intelligence, Lilly (1964) has made the generalization that no "deep-sea adult cetaceans" exist with a brain smaller than 900 to 1000 gm, which is a critical minimal correlate of language development in the maturing human child (Lilly, 1961). He goes on to suggest that to live in the sea breathing air with a mammalian physiology and a mammalian skin, requires a large brain for a successful adaptation over the millennia.

Since very little brain weight data exists for the small odontocetes, we decided to test Lilly's minimum brain weight hypothesis and to expand the work of Dubois and Wirz with an interspecies study of brain weight, body weight, and body length in *T. truncatus*, *Lagenorhynchus obliquidens*, *Phocoenoides dalli*, and *Delphinus delphis bairdi*. Also, because Warden (1951) has noted that a rough measure of intelligence among vertebrates is the ratio of the weight of the brain to that of the spinal cord (in fishes the brain weighs less than the cord; in the horse the ratio is about 2.5:1; in the cat 4 or 5:1; in apes about 8:1; and in man 50:1), we compared our brain weight data to the cord weights.

Subjects and Procedure

The classification, age, and sex of the porpoises used in this study are given in Table 1. Five animals were used (included in Fig. 1) for whom cord data was not

Table 1. Comparisons of body length, body weight, brain and cord weights in some cetaceans.

Sex	Age	Body wt, Kg	Body Length cm	Brain wt, g	Cord wt, g	Body Weight :brain ratio	Body Length :brain ratio	Brain :cord ratio
A) <i>Tursiops truncatus</i>								
F	adult	60	182	1353	35	44:1	135:1	39:1
F	adult	102	198	1588	35	64:1	125:1	45:1
F	young	80	158	1300	32	62:1	122:1	39:1
F	adult	120	235	1296	36	93:1	181:1	36:1
F	Average	91	193	1384	35	66:1	139:1	39:1
M	adult	95	182	1389	31	68:1	131:1	45:1
M	adult	100	212	1555	40	64:1	136:1	39:1
M	adult	63	154	1540	34	41:1	105:1	45:1
M	4 mos	40	133	1268	35	32:1	105:1	36:1
M	Average	75	176	1438	35	51:1	122:1	41:1
Average		83	185	1411	35	59:1	131:1	40:1
B) <i>Lagenorhynchus obliquidens</i>								
F	adult	79	172	1079	31	73:1	159:1	34.8:1
M	adult	110	188	1285	37	86:1	146:1	34.7:1
M	adult	70	172	1046	30	67:1	164:1	34.8:1
M	adult	100	198	1136	33	88:1	174:1	34.4:1
Average		90	183	1137	33	79:1	161:1	34.5:1
C) <i>Phocoenoides dalli</i>								
F	adult	70	180	760	29	105:1	236:1	26:1
F	adult	115	191	948*	35*	121:1	202:1	27:1
F	adult	110	185	793	30	139:1	222:1	26:1
Average		98	185	834	31	122:1	222:1	26:1

* After one week in formalin

Fig. 1. Comparison of brain weight to body weight data for small dolphins, contrasted with data of Lilly (1964).

taken: One adult male *P. dalli*, one adult female *L. obliquidens*, and three adult male *D. bairdi*.

When the animal had stranded on a beach or had died in captivity and the necropsy could be performed ashore, actual measurements were made of brain weight, cord weight, body weight and body length. We determined that experienced collectors could estimate the body weight of an adult specimen within 5 percent. When the necropsy was performed at sea, usually for the purpose of quick fixation of the central nervous system, weighing of the whole body was impractical and estimates were used. Ages of these animals were determined on the basis of body size, condition of teeth, and appearance of bone.

The specimens were decapitated so that all transections were made uniformly at the level of the occipital condyles. The brains were removed after dorsal craniotomy. The cords were taken after removing the dorsal spines of the cervical and thoracic vertebra, exposing the spinal canal. With the exception of one brain and cord (see Table 1) all material was weighed in fresh condition.

Results and Discussion

Although our brain weight data for *T. truncatus* compares favorably with figures reported by Lilly (1964), we found his minimum brain weight hypothesis to be oversimplified. All specimens of *T. truncatus* and *L. obliquidens* did have brain weights over 1000 gm; however, none of the *P. dalli* or *D. bairdi* had a 1000 gm brain. The *D. bairdi* and all but one *P. dalli* brains were

below the minimum 900 gm weight which Lilly proposed as a criterion for the adaptation of cetaceans to a marine environment (the one brain over this weight was weighed after one week in formalin). One adult *P. dalli* had a brain weight of 760 gm (ecological and physiological differences of *T. truncatus*, *L. obliquidens* and *P. dalli* have been defined by Ridgway (1966)).

As seen in Table 1, *T. truncatus* has the highest ratio of brain weight to spinal cord weight. All *T. truncatus* had higher brain to cord ratios (average 40:1) than all *L. obliquidens* (average 34.5:1) measured, and, in turn, all *L. obliquidens* had higher ratios than all *P. dalli* (average 26:1). These ratios approach the 50:1 ratio given for man (Warden, 1951) and are much higher than those given for subhuman primates (8:1). Therefore, according to Warden's "approximate measure of intelligence," the small delphinids would rank between man and lower primates.

The brain weight and cord weight data presented here represents significant interspecies variation. If the comparative brain structure work of Wirz and Morgane could be repeated on an interspecies basis along with interspecies studies of delphinid behavior, similar to the *T. truncatus* studies of Kellogg, McBride and Hebb, and Lilly, one should gain a more comprehensive understanding of relative intelligence in the delphinids, and such correlation as may exist between brain, cord ratios and intelligence.

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