RESPIRATORY PATTERNS DURING REST AND SLEEP OF WILD KILLER WHALES (ORCINUS ORCA)

Jeff Jacobsen, Dept. Biological Sciences, Humboldt State University, Arcata, Calif., 95521.
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ABSTRACT

The respiratory patterns of the resident orca pods that frequent the Johnstone Strait area of Northern Vancouver Island were studied during July through Sept., 1982 to 1983. The principal research tool has been an OS-3 behavioral event recorder, a hand held computer that stores the time that a subject identification code is keyed in. The times of apnea of up to ten whales have been recorded per trial with no break in visual contact. Dive and float durations were then computed for each whale. The breathing pattern during rest is generally a series of 3-7 short (10-45 sec) dives, followed by a long dive (1.5-3 min). Several maternal subgroups (cows and their offspring of either sex) may line up perpendicular to the direction of travel and coordinate their dives. A subgroup at one end of the line submerges for a long dive, followed, a minute or so later, by the next, and so on down the line. During rest, the whales may change positions within the line, and travel at about 2-4 knots. The transition into the sleep pattern is marked by a decrease in swimming speed to 2 knots or less, no further changes of position, an increase in the duration of long dives to 3-5 minutes, and an increase in the number of floating bouts during the series of short dives. The orca often orient into the tidal current, maintaining their geographic position within the Strait. This rest and sleep pattern has been observed for periods of up to eight hours, and can be interrupted by boat traffic. Due to the distinct and routine diving sequence of maternal subgroups within the resting line, this method may be useful in determining the social structure of previously unobserved pods.

INTRODUCTION

The information presented in this poster is part of an attempt to describe the various behaviors (foraging, traveling, rest, and play) of killer whales by measuring their respiratory activity. My first efforts, which relied on the tried and true method of a stopwatch and written field notes, revealed several characteristic patterns, but were limited in sample size and in the number of whales that could be timed at once. These limitations seemed most critical when it came to analyzing the whale's coordinated rest pattern. I have since solved this problem with a field computer, and now divide the rest pattern described in my ethogram (Jacobsen, in press) into rest and sleep. I describe the new method below, and present the characteristics of the two patterns. I also describe a deviation from the pattern that I believe was due to illness, plus some social aspects of the coordination amongst individuals. In the discussion section I briefly mention several factors that I think are important in understanding the dynamics of the pattern and in designing further research projects.

METHODS

The study area is the Johnstone Strait, a 2 mile wide portion of the Inside Passage at the north end of Vacouver Island, British Columbia (figure 1). During the summer months, resident pods of killer whales can be sighted daily in the Strait, feeding on migrating salmon. Individual orcas are photo-identified with the system developed by Bigg (1982). Of the 13 northern resident pods, the three A-pods have comprised about 80% of all sightings during the study period of 1982 to 1984, hence are the focal group. All observations were made from a 4.2 m inflatable boat equipped with a 25 h.p. outboard motor. A position perpendicular to and at least 20 m from the orcas was maintained during the trials (figure 2).

Fig 2 missing

The principal research tool has been an Observational Systems OS-3 Event Recorder (figure 3). This hand-held computer stores the time to the nearest tenth of a second that a subject identification code is keyed in. With this computer I have been able to record the times of respiration of up to ten whales simultaneously, with no break in visual contact. To distinguish between respirations made before dives and made during periods of floating at the surface, the row of ten toggle switches were used to simultaneously record the onset and end of floating bouts. Comment flags were interjected into the data stream to reference corrections and peripheral behaviors recorded manually in the field notes. Trial durations were a minimum of thirty minutes. Data was stored on audio cassettes, then analyzed at the end of the field season.

RESULTS

I have focused the analysis to date on the respiratory patterns observed when the whales were aligned in their coordinated rest and sleep positions. The pattern during rest is generally a series of 3-7 short (10-45 sec) shallow dives followed by a long (1.5-3 min) deep dive. Several maternal subgroups may line up perpendicular to the direction of travel and coordinate their dives (figure 4). The subgroups do not all submerge simultaneously for the long dive, however. Instead, a subgroup at one end of the line submerges first, followed a minute or so later by the next, and so on down the line (figures 5-7). For a period of one to about 4 minutes (depending on the number of subgroups in the line), all the whales will be submerged. This is represented diagramiticly in figure 7, but the actual relative positions of the whales at depth is unknown. The subgroups return to the surface in the same order in which they dove and repeat the pattern (figures 8 and 9, then 4) During rest, the whales swim at about 2-4 knots, and they may change positions within the line.

The transition into the sleep pattern is marked by a decrease in swimming speed to 2 knots or less, no further changes of position, an increase in the duration of long dives to 3-5 minutes, and an increase in the number of floating bouts during the series of short dives. During sleep the whales often orient into the 1-2 knot tidal current, and therefore do not change their position in the Johnstone Strait. A sleeping line can be disturbed by boat traffic, which generally has the effect of causing the whales to return to the rest pattern and perhaps changing direction. Lines of resting and sleeping whales have been observed for periods of up to eight hours.

Comparison of Rest and Sleep

	Rest	Sleep
Swimming speed	2-4 knots	2 knots or less
Long dive time	1.5-3 min	3-5 min
Floating bouts	infrequent	frequent
Positional changes	frequent	infrequent

One female, A-10, had a different respiratory pattern than the rest of the whales in the line (see figure 4 for her position). In relation to her own subgroup, A-10 tended to be the last one to dive and the first to surface (figures 4-9). In figure 10, A-10's dive times are compared with another female's in the line, A-30 (position shown in figure 4), during equal durations of both rest and sleep. During rest, although both whales took about the same number of dives, A-10's long dives (dives greater than or equal to 90 sec.) were on the average 29.3 seconds less than A-30's. When the whales were in the sleep pattern, A-30 increased her long dives to an average of 310.8 seconds, but A-10 increased hers to an average of only 201.9 seconds, and took 15 more breaths in the same amount of time. Since A-10 was moving lethargicly, tended to float more often than the others, and occasionally exhaled mucous, I suspect that she had a respiratory illness. This may explain why she was unable to change from a rest to a sleep pattern with the rest of the group.

The most basic social unit among orcas is the maternal subgroup, consisting of a cow and her offspring of either sex (Bigg, 1981; Heimlich-Boran, in press; Jacobsen, 1985 and in press). A pod is an association of one to several maternal subgroups. This social organization is evident in the relative positions of individuals within a resting group, and in the sequence of their surfacings. When one subgroup is resting by itself, the youngest calves swim closest to the cow on either side. Older individuals (mature males and postreproductive and/or barren cows) swim outside of the calves. As this group rises to the surface to breathe, the cow breathes first, followed a few seconds later by her calves and other individuals. This sequence of surfacings is so consistant that reliable assumptions can be made regarding relatedness among individuals.

The degree to which maternal subgroups line up to rest may be an indication of their association history. Subgroups that are frequently sighted traveling or foraging together (such as the 9 subgroups of the 3 A-pods) will readily align and coordinate their movements while resting. Pods that are rarely sighted in the Johnstone Strait (such as the D or G pods), generally form their own resting lines that are not coordinated with the others. For example, during the study period, one subgroup from the C pod began associating with the A pods with increasing frequency, and also increased its coordination during rest with the A pod subgroups.

DISCUSSION

Perhaps the most puzzling aspects of the respiratory patterns described above, is that the whales continue to swim while sleeping instead of floating, and that their dive times increase. I suspect that several factors are involved, and will briefly discuss them below.

To my knowlege, very little experimentation has been done on sleep in dolphins. The work done by Lilly (1967) and more recently by Koval'zon and Mukhametov (1982), shows that sleep occurs alternately in one hemisphere of the brain at a time. This allows one hemisphere to remain active to coordinate breathing, a concious act in cetaceans. It seems reasonable that the coordinated alignment and routine breathing pattern of the group would fascilitate rest.

The phenomenon of assisted locomotion (Norris and Prescott, 1961) probably plays an important role also, especially for the calves. Due to the way water flows over a dolphin's body, a calf can be carried by its mother by placing itself against her flank. The close, often touching proximity of individuals within the line suggests that at depth this phenomenon is important in their alignment. It also suggests that cows with calves may need to limit the duration of their long dives according to the needs of their calves. Hence one would expect a difference between cows with calves and bulls, and perhaps cows without calves. Bulls do seem to take fewer dives than cows at times, but the analysis of the data to date does not show any significant difference.

An important aspect of this resting behavior that is virtually unknown is the depth of the long dives, and the alignment of the individuals and subgroups at depth. Within a depth of three times the body diameter, surface turbulence affects the swiming motions of a dolphin (Blake, 1983). This sets a minimum depth, below which the resting whales would not be hindered. As the orcas dive for their long and deep dive, they typically arch their backs and submerge at a steeper angle. The momentum of this dive may carry them to a depth where they could glide with minimal swimming movements, and then return to the surface assisted by bouyancy.

CONCLUSION

The method described above has proven to be an efficient way to collect accurate respiratory data on many subjects at once, and to greatly fascilitate subsequent analysis. I have been able to refine the resting behavior described in my ethogram (Jacobsen, in press) into the two categories described here as rest and sleep. The social aspects of this coordinated breathing pattern are also important, and may prove useful in determining the social structure of previously unobserved groups of killer whales.

This study is by no means complete, however, and the information presented here is best viewed as a simplified introduction to the respiratory behavior of the orca. Future data analysis will include further comparisons among individuals within the resting lines, and in other behaviors as well. This is still only a surface view, and the interactions among individuals at depth are likely to be important. Underwater observation, either directly via diving or submersables, or by remote systems, is therefore the next step in this and many other cetacean research projects.

ACKNOWLEDGEMENTS

I've been at this orca research for over seven years by now, with no end yet in sight, and it seems that the list of people deserving acknowledgement doubles each year. My sincerest thanks to you all. The people most involved with this particular project include: Dick Holm of Observational Systems whose wonderful gadget has made all this possible; Dr. Mike Bigg, whose identification system made the other half of the project possible; Patricia Smith, who helped with much of the analysis; and field assistants Linda Campbell and Patty Gallagher.

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NOTE: After a few conversations at the conference I have learned of several other papers published regarding sleep in cetaceans. Apparently it is still an open question whether or not unihemispheric sleep exists in dolphins. If you contact me in a month or so I will have these references and prolly a whole new set of ideas on the topic. JJ, Dec 2, 1985.

Figure 1. Study Area

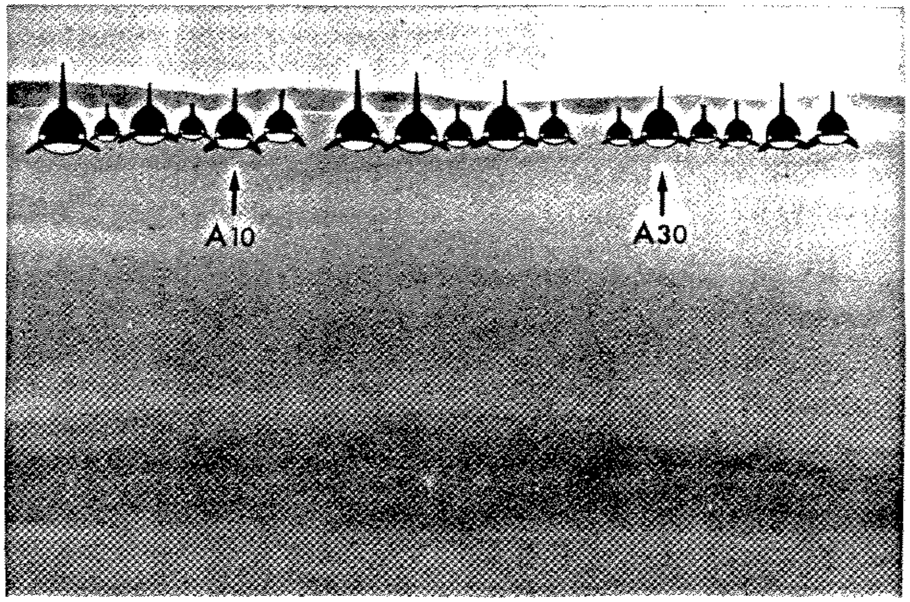

Figure 4. All subgroups at surface during period of short, shallow dives. Positions within line of A-10 and A-30 indicated (see text and figure 10)

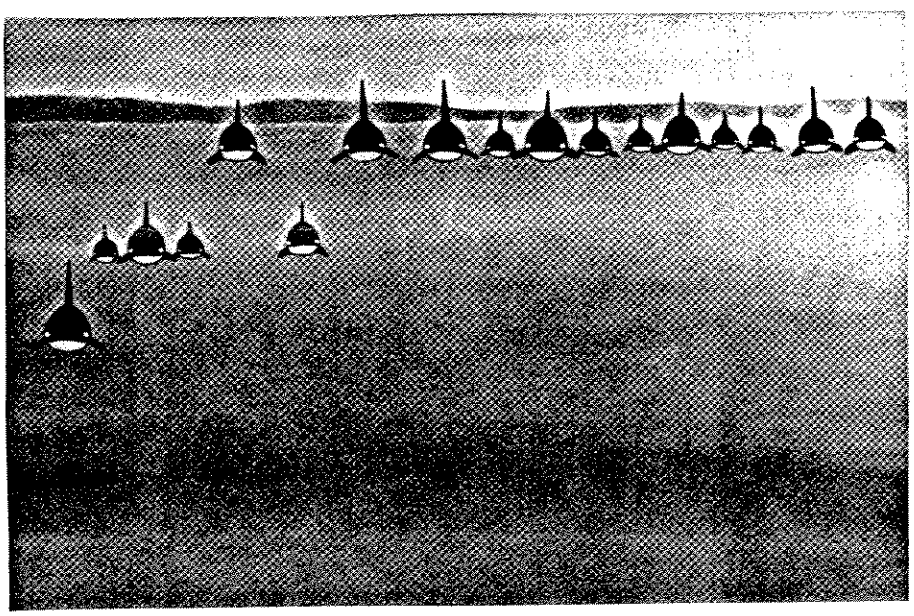

Figure 5. The subgroup at one end of the line begins its long, deep dive first; A-10 remains.

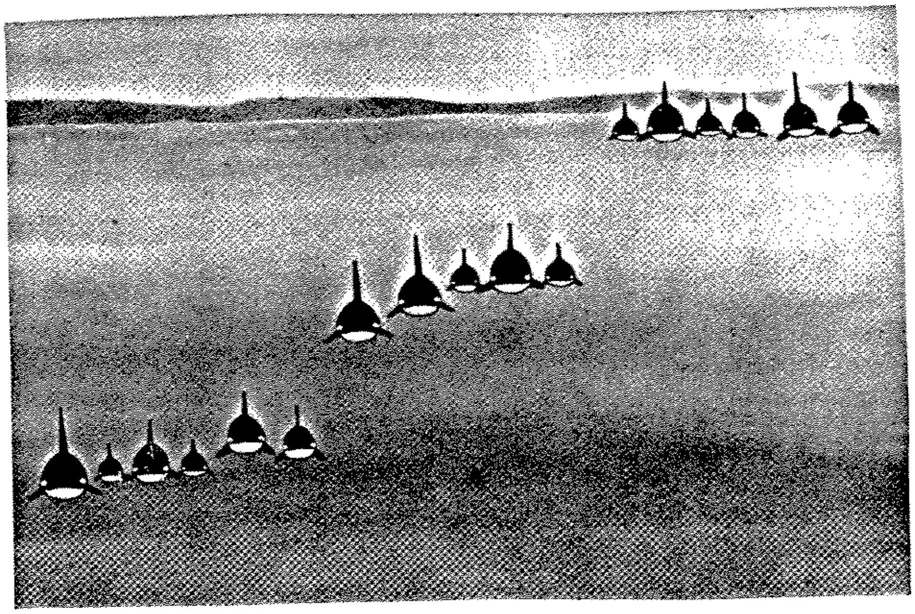

Figure 6. A-10 has dove, and then the second subgroup dives.

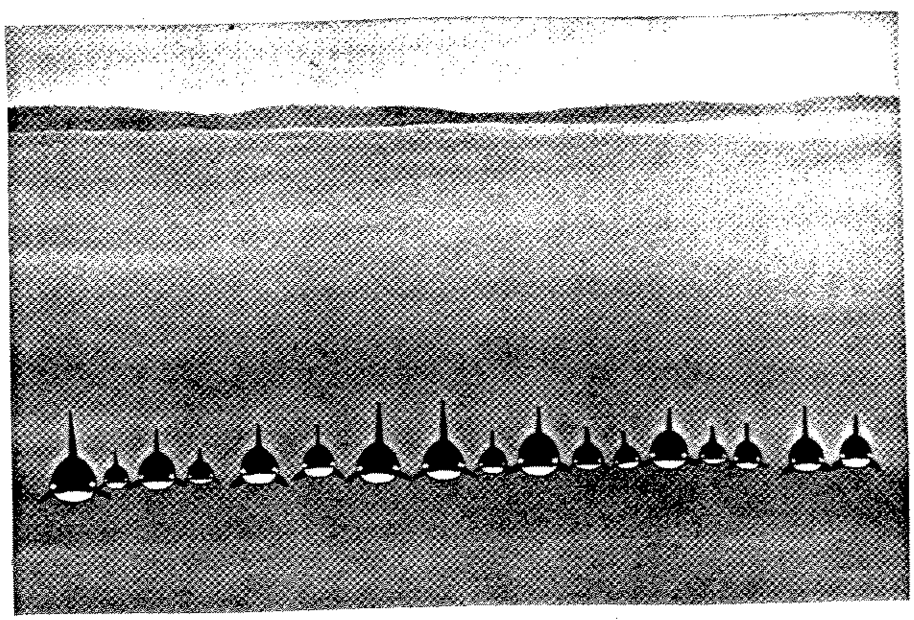

Figure 7. The third subgroup dives. The alignment at depth depicted here is for diagramatic purposes only! The actual alignment and depth are unknown.

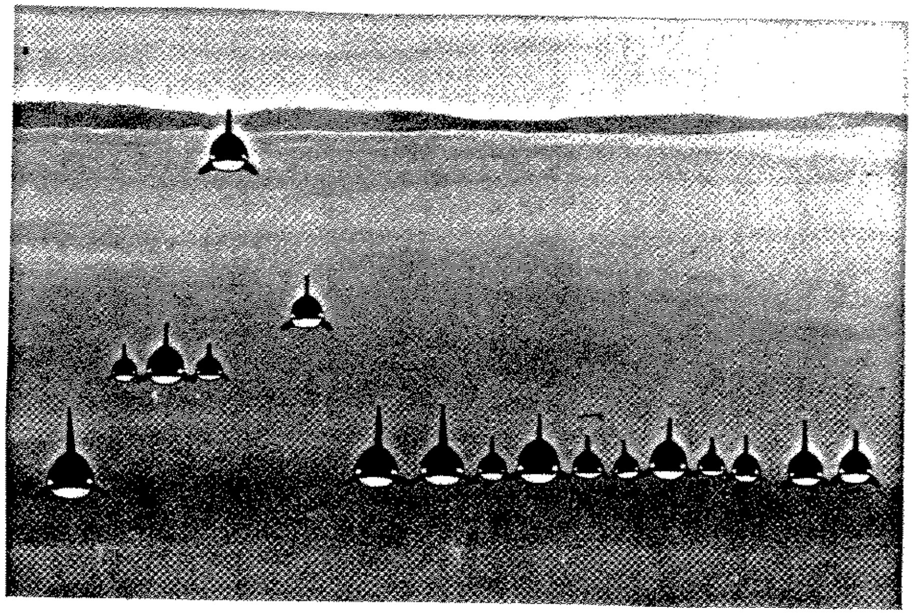

Figure 8. The first subgroup surfaces, with A-10 arriving first.

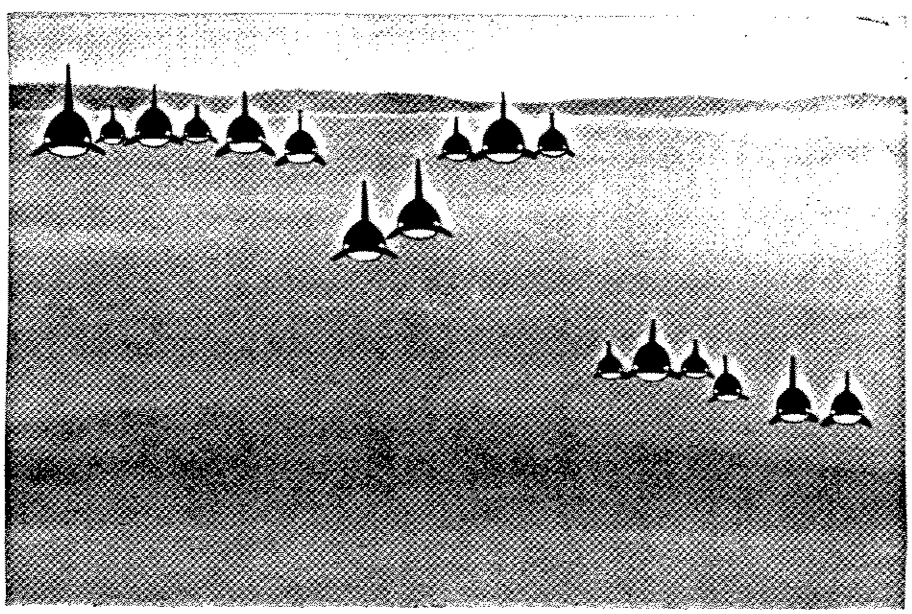

Figure 9. The second subgroup returns to the surface, then is followed by the third, and the pattern repeats.

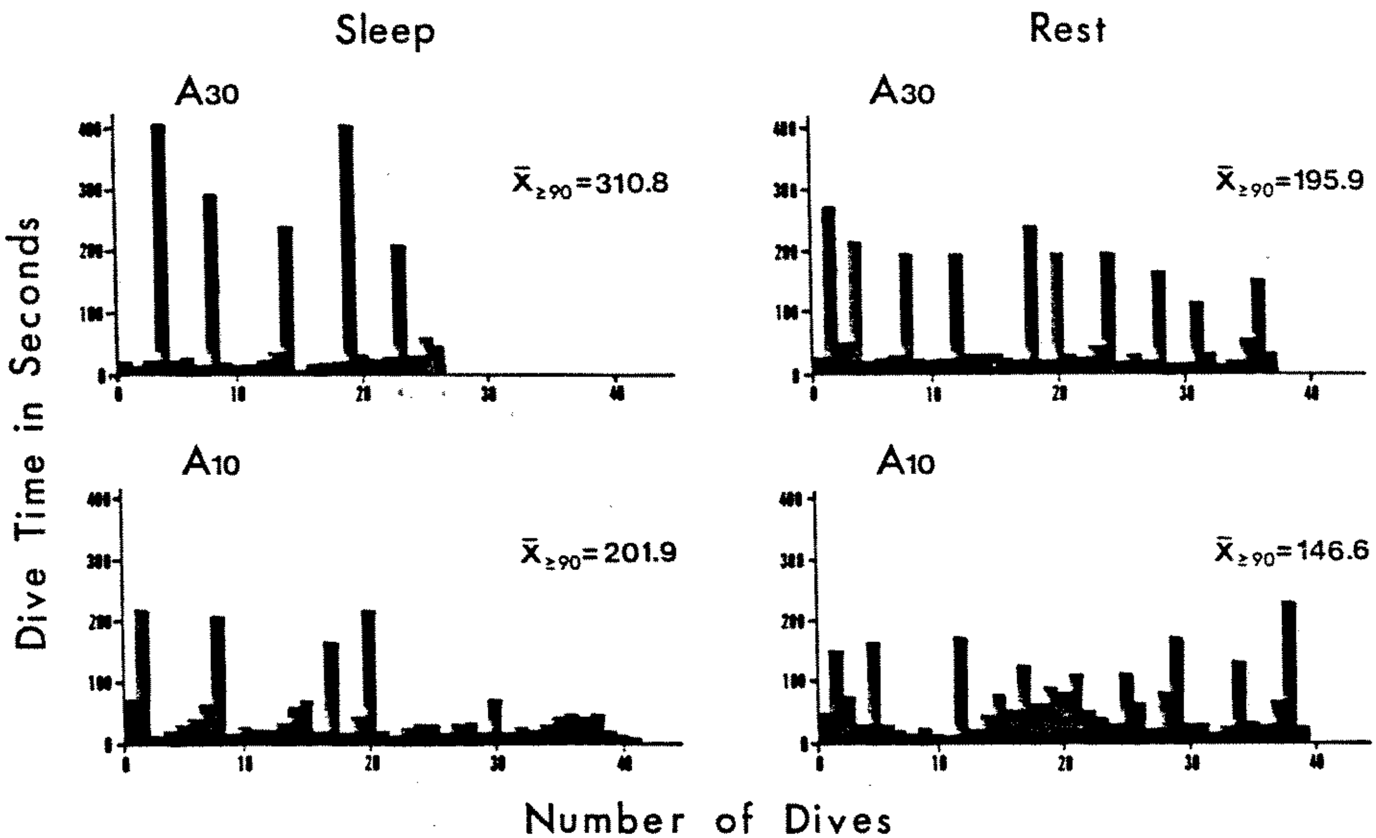

Figure 10. Comparison of dive times for A-10 and A-30 for equal durations of sleep (33 min) and rest (44 min). The average of all dives greater than or equal to 90 seconds are shown.