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Annotated Bibliography of Publications from the U. S. Navy's Marine Mammal Program

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FOREWORD

The Navy's Marine Mammal Program, originally a cooperative effort of the Naval Ordnance Test Station and the Navy Missile Center, is now conducted by Space and Naval Warfare Systems Center San Diego (SSC San Diego), previously named the Naval Command, Control and Ocean Surveillance Center Research, Development, Test and Evaluation Division (NRaD) and the Naval Ocean Systems Center (NOSC).

This publication provides an updated bibliography of the Navy's Marine Mammal Program. This update contains works published through 31 December 1997. Some 220 publications are added to the previous edition, published in February 1992 (NRaD Technical Document 627, Revision C), plus two new chapters (Neural Networks and Reintroduction/Return to the Wild), reflecting areas of increased interest and importance. For a bibliography of literature published prior to 1963, see Squire, 1964 in the Miscellaneous section of this document.

This revision, like previous revisions, is organized into subject areas. The Miscellaneous subject area contains publications about general topics, evolution, taxonomy, conservation, and history of the Marine Mammal Program. Each publication is cited once; cross-referencing between subject areas is not provided.

An Internet website is organized both in this manner and in a total alphabetical list by principal authors.

Entries in this bibliography include publications by contractors and by other non-Navy researchers whose materials or facilities were provided by the Navy.

In-house publications are identified by the acronyms NOTS (Naval Ordnance Test Station), NUC (Naval Undersea Center), NSWC (Naval Surface Weapons Center), NOSC (Naval Ocean Systems Center) and NRaD (Naval Command, Control and Ocean Surveillance Center Research, Development, Test and Evaluation Division). These publications consist of TMs (Technical Manuals), TPs (Technical Publications), TRs (Technical Reports), and TDs (Technical Documents).

The majority of the papers listed were published in established technical journals, books, or in proceedings of significant conferences where Navy efforts were reported. These are available from the publishers or technical libraries.

Copies of the Navy in-house publications can be obtained from the National Technical Information Service, Springfield, VA 22161; the cost varies according to the size of the document. A select number of these publications can be found at the website indicated above. In the case of some conference presentations, abstracts can be obtained from the authors by written request to the SSC San Diego Public Affairs Office at the following address:

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BRIEF HISTORY OF THE NAVY'S MARINE MAMMAL PROGRAM

The U.S. Navy's Marine Mammal Program had its origin in the acquisition, in 1960, of a Pacific white-sided dolphin for hydrodynamic studies. Navy scientists designing torpedos had heard accounts of the hydrodynamic efficiency of dolphins, and were interested in determining whether dolphins did in fact have special characteristics that might be applied to the design of the underwater missiles. Work with the white-sided dolphin indicated that she possessed no unusual physiological or hydrodynamic capabilities, but it was suspected that limitations of the physical facilities and the measurement capabilities at the time might have affected the study data. Under a new program, research on dolphin hydrodynamics has been resumed, with the same goal the original work had—to determine if the dolphin does indeed possess a highly evolved drag reducing system. The capabilities for undertaking this work are now greatly improved and include instrumentation for measurements that previously could not be made. Among the possible drag-reducing mechanisms being studied are skin compliance, biopolymers, and boundary layer heating, which may or may not work synergistically.

Early Navy marine mammal work centered around Point Mugu, California, where a modest facility for research and exploratory development gradually evolved on a sand spit between Mugu Lagoon and the ocean. The program got underway in 1963. The primary interests were in the study of the marine mammals' specially developed senses and capabilities (such as sonar and deep-diving physiology) and also how dolphins and sea lions might be used to perform useful tasks. A major accomplishment was the demonstration that trained dolphins and sea lions could be worked untethered in the open sea with great reliability. In 1965, a Navy dolphin named Tuffy participated in the Sea Lab II project off La Jolla, California, carrying tools and messages between the surface and aquanauts operating out of the habitat 200 feet below.

In 1967, the Point Mugu facility and its personnel were relocated to San Diego and placed under a newly formed organization which has since undergone a number of name changes, including Naval Undersea Center (NUC); Naval Ocean Systems Center (NOSC); Naval Command, Control and Ocean Surveillance Center Research, Development, Test and Evaluation Division (NRaD); and, currently, Space and Naval Warfare Systems Center San Diego (SSC San Diego). Shortly after the headquarters move to San Diego in 1967, a laboratory was established in Hawaii at the Marine Corps Air Station on Kaneohe Bay. Some of the personnel and animals at Point Mugu transferred to the Hawaii Laboratory, and later the rest of the operation moved to a new facility on Point Loma in San Diego. Here the research and development program begun at Point Mugu has continued. This has included further studies of the capabilities of marine mammals; development of improved techniques for diagnosis and treatment of health problems; neurophysiological studies, using behavioral and other non-invasive techniques, to gain a better understanding of how the large dolphin brain functions; development of instrumentation for determining, by brain wave activity, the hearing range of a cetacean; and investigation of how dolphins produce the sounds they make.

Marine mammal work at the Hawaii Laboratory was concerned with behavioral studies, reproductive physiology, further research on the dolphin echolocation system, and investigation of the potential of marine mammals for performing useful tasks more efficiently, safely, and cost effectively than is possible using human divers or submersibles.

In 1993, as the result of Base Closure and Realignment Commission (BRAC) action, the Hawaii Lab was closed, and the majority of the animals moved to San Diego. A small group of animals remained, participating in joint research with the University of Hawaii Institute of Marine Biology.

In its operational systems, the Navy employs dolphins and sea lions to perform underwater surveillance for object detection, location, marking and recovery, working under the close supervision of their Navy handlers. On cue from its handler an animal searches a specific area using its sensitive underwater directional hearing (sea lions) or its biological sonar (dolphins). The animal reports to its trainer when the target object is detected. The trainer then makes a determination based on the situation what action to take—whether to send the animal to mark or recover the object, or employ human divers to make a recovery.

The Navy uses dolphins in operational programs for swimmer defense—to detect swimmers, divers and swimmer delivery vehicles, and, if the handler determines the situation warrants, to mark them; and for mine countermeasures—to detect bottom mines and moored mines. Dolphins are used for these tasks because their extraordinary natural biological sonar capabilities enable them to find objects in waters where hardware sonars do not work well due to poor acoustic environmental conditions. The swimmer defense system was deployed to Vietnam in 1970-71 and to the Persian Gulf in 1987-88.

An operational system developed in Hawaii employs California sea lions to locate and attach recovery hardware to unarmed instrumented test ordnance, which is fired or dropped into the ocean and then must be recovered. Traditional recovery involved human divers, who are handicapped by brief working times on the bottom, poor visibility, currents, and the requirement for medical personnel, a recompression chamber and other surface support. The sea lion recovery system, which eliminates this complex and potentially dangerous recovery approach, consists simply of a small rubber boat, a sea lion, and two or three handlers. When the boat arrives at the recovery site, the sea lion is sent over the side. Trained to detect the ordnance by an acoustic beacon placed in the object before the test, the sea lion indicates if he hears the beacon and accepts a bite plate to which an attachment device is mounted. A strong line tied to this device is payed out from the boat as the sea lion swims down to the object and attaches the device. The sea lion then releases the bite plate and returns to the boat for a well-deserved reward of fish while a crane is used to pull the object off the bottom. The system, which has a recovery capability to a depth of 1,000 feet, became operational in 1975 and has been in service use since that time.

In a similar project, called Deep Ops, a pilot whale and two killer whales demonstrated their ability to recover objects from greater depths. The recovery device the whales attached to the target object, a dummy torpedo containing an acoustic beacon, incorporated a hydrazine gas generator which was activated upon attachment of the device to the torpedo. The generated gas filled a large lift bag which raised the torpedo to the surface. Using this device, the pilot whale successfully recovered the torpedo from a depth of 1,654 feet. Although much was learned from the Deep Ops project, work with pilot and killer whales, the largest of the dolphins, has not been continued.

The capabilities of belugas, or white whales, have been investigated at the SSC San Diego and Hawaii facilities, San Clemente Island, and torpedo test ranges in Seattle and Canada. Although belugas are inshore and estuarine animals which enter rivers for calving and feeding, they were found capable of diving to at least 2,100 feet. In studies to determine their ability to recover inert experimental torpedoes at a test range, the belugas attached the recovery device to a dummy torpedo at 1,300 feet, the maximum depth available.

All Navy marine mammal training is performed using positive reinforcement with food reward, that is, the animals are rewarded with fish for performing their tasks correctly but they are not punished for failure to perform them. As the result of allegations of animal abuse within the Navy's mammal program, the Assistant Secretary of the Navy invited two in-depth reviews by the presidentially appointed Marine Mammal Commission. The reviews in 1988 and 1990 resulted in satisfactory to outstanding ratings for all aspects of the Navy program. Additionally, the National Marine Fisheries Service, which maintains oversight responsibility for all marine mammals in the care of people in the U.S., reported findings in the scientific literature that showed the Navy's dolphin survival rate is the highest among all organizations holding large numbers of marine mammals. This was attributed by the researchers conducting the study to "superior husbandry." Dolphin survival rate in the wild is reported in the scientific literature as 92 to 95 percent; the Navy's dolphin survival rate for the past 10 years has been 95 to 97 percent, and during one recent period the Navy maintained an unprecedented 100-percent survival rate for more than a year and a half for the 140 marine mammals it was holding at the time.

Navy dolphins are maintained in their natural environment—bays and harbors of the Pacific and Atlantic Oceans—in open-mesh enclosures that provide a normal echolocation environment and ample socialization opportunities except during medical procedures and actual training periods. Navy dolphins are trained untethered in the open ocean on an almost daily basis, and yet in the course of 30 years of such training and many thousands of these open-ocean sessions only seven of the Navy's dolphins have failed to return to their enclosures.

The Navy's marine mammal systems are subject to the same rigorous test and evaluation process required of any Navy system prior to fleet acceptance. Systems failing to met acceptable standards of effectiveness and reliability are rejected by the Navy. The Navy's operational marine mammal systems are efficient, reliable and cost-effective.

This Annotated Bibliography of Publications from the Navy Marine Mammal Program provides an indication of the range and scope of projects undertaken since the beginning of the program in 1963.

CONTENTS

1. SOUND/SONAR/COMMUNICATION

Altes, R. A., W. E. Evans, and C. S. Johnson. 1975. Cetacean Echolocation Signals and a New Model for the Human Glottal Pulse. *Jour. Acoust. Soc. Am.* **57** (5): 1221-1224.

A theoretical explanation for cetacean sonar systems can also be applied to human speech. The theory leads to a mathematical model of the human glottal pulse that is considerably different from those employed in the past.

Altes, R. A. and S. H. Ridgway. 1980. Dolphin Whistles as Velocity-sensitive Sonar/Navigation Signals. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 853-854.

A certain type of dolphin whistle that has been classified as a distress whistle but which also occurs under other circumstances is very similar to signals that can be used for accurate Doppler measurement. On theoretical grounds, such whistles have characteristics that might make them useful for sonar navigation, but behavioral experiments are needed.

Au, W.W.L., R. W. Floyd, R. H. Penner, and A. E. Murchison. 1974. Measurement of Echolocation Signals in the Atlantic Bottlenosed Dolphin, *Tursiops truncatus* Montagu, in Open Waters. *Jour. Acoust. Soc. Am.* **56** (4): 1280-1290.

Echolocation signals of two bottlenosed dolphins echolocating on targets at distances of 60 to 80 yards were measured. Peak energies between 120 and 130 kHz were recorded, with sound pressure levels at least 30 dB higher than any previously reported.

Au, W.W.L. and C. E. Hammer. 1978. Analysis of Target Recognition via Echolocation by an Atlantic Bottlenosed Porpoise *(Tursiops truncatus*). (Abs.) *Jour. Acoust. Soc. Am.* **64** (Suppl. 1): S87.

From targets previously used for a study of porpoise echolocation, echoes of porpoise-like signals were obtained and analyzed. The shape of the spectrum was predominantly influenced by the first two echo components, those from the front face and the interior boundary of the rear face. Matched-filter analysis corresponds closely with the animal's performance.

Au, W.W.L., R. W. Floyd, and J. E. Haun. 1978. Propagation of Atlantic Bottlenosed Dolphin Echolocation Signals. *Jour. Acoust. Soc. Am.* **64**: 411-422.

The propagational characteristics of high-frequency signals (peak energies above 100 kHz) were determined by a series of measurements made in open water. The 3-dB broadband beamwidth was found to be approximately 10 inches in both the horizontal and vertical planes. The major axis of the vertical beam was directed at an angle of 20 inches above the plane defined by the animal's teeth.

Au, W.W.L. 1980. Echolocation Signals of the Atlantic Bottlenosed Dolphin (*Tursiops truncatus*) in Open Waters. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 251-282.

A review, with additional previously unpublished data.

Au, W.W.L. and C. E. Hammer. 1980. Target Recognition via Echolocation by *Tursiops truncatus.* In: *Animal Sonar Systems,* R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 855-858.

Target recognition and discrimination behavior was studied as a function of target composition and internal structure. The targets were then acoustically examined using a simulated dolphin echolocation signal to determine the salient cues that could enable the animal to discriminate the targets.

Au, W.W.L., R. J. Schusterman, and D. A. Kersting. 1980. Sphere-Cylinder Discrimination via Echolocation by *Tursiops truncatus.* In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 859-862.

Discrimination of spherical and cylindrical targets of the same material but with dimensions chosen such that they had overlapping target strengths was demonstrated. Acoustic examination of echoes from the targets indicated they were very similar, but it was found that the water-surface-reflected component of the echoes differed with the two shapes and apparently provided the essential cue.

Au, W.W.L. and K. J. Snyder. 1980. Long-Range Target Detection in Open Waters by an Echolocating Atlantic Bottlenosed Dolphin. *Jour. Acoust. Soc. Am.* **68** (4): 1077-1084.

The dolphin was found to be capable of detecting a 7.62-cm diameter stainless steel water-filled sphere at 113 m (50 percent target detection threshold range). Results with this sphere were congruent with those obtained previously with a sphere less than half its diameter.

Au, W.W.L. and R. H. Penner. 1981. Target Detection in Noise by Echolocating Atlantic Bottlenosed Dolphins. *Jour. Acoust. Soc. Am.* **70** (3): 687-693.

The capability of two dolphins to detect a 7.62-cm water-filled stainless steel sphere was tested in the presence of white noise. The response of an ideal energy detector was found to match the behavioral results as a function of the echo signal-to-noise ratio.

Au, W. W. L, R. H. Penner, and J. Kadane. 1982. Acoustic Behavior of Echolocating Atlantic Bottlenose Dolphins. *Jour. Acoust. Soc. Am.* **71** (5): 1269-1275.

A click detector was used to monitor acoustic emissions of two dolphins performing a target detection task in white noise. Average number of clicks emitted per trial increased with masking noise until a particular level was reached, then decreased with further increases in noise level. Response levels and click intervals were also analyzed.

Au, W.W.L. and P. W. B. Moore. 1982. Directional Hearing in the Atlantic Bottlenosed Dolphin *(Tursiops truncatus).* (Abs.) *Jour. Acoust. Soc. Am.* **70** (Suppl. 1): S42.

Directional hearing sensitivity in the horizontal plane was measured for pure-tone frequencies of 30, 60, and 120 kHz (for vertical beam pattern results, see Moore and Au, 1981). The receiving directivity index for beam patterns in both the vertical and horizontal planes was 10, 15, and 21 dB respectively for the three frequencies.

Au, W.W.L., D. A. Carter, R. H. Penner, and B. L. Scronce. 1982. Beluga Whale Echolocation Signals in Two Different Ambient Noise Environments. *Jour. Acoust. Soc. Am.* **72** (Suppl. 1): S42.

In Kaneohe Bay, Hawaii, the echolocation clicks emitted by a beluga during a target identification task had higher peak frequencies and higher bandwidths than were measured earlier in the lower ambient noise environment of San Diego Bay.

Au, W.W.L. and D. W. Martin. 1983. Insights into Dolphin Sonar Discrimination Capabilities from Broadband Sonar Discrimination Experiments with Human Subjects. (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S73.

When digital recordings made of echoes from targets ensonified with a dolphin-like signal were played back at a slower rate to subjects, humans could make fine target discriminations about as well as dolphins can under less controlled conditions.

Au, W.W.L. and P. W. B. Moore. 1984. Receiving Beam Patterns and Directivity Indices of the Atlantic Bottlenosed Dolphin (*Tursiops truncatus*). *Jour. Acoust. Soc. Am.* **75** (1): 255-262.

Receiving beam patterns were measured in both the vertical and horizontal planes for frequencies of 30, 60, and 120 kHz. Beam patterns in both planes became narrower as the frequency increased.

Au, W.W.L. and C. W. Turl. 1984. Dolphin Biosonar Detection in Clutter: Variation in the Payoff Matrix. *Jour. Acoust. Soc. Am.* **76** (3): 955-957.

A bottlenosed dolphin was trained to detect targets in the interference of a clutter screen (spaced cork spheres in a rectangular array). The number of pieces of fish given for correct detections and rejections was varied. Increased food reinforcement resulted in an increase in both correct detection and false alarm rates, but detection sensitivity was approximately constant.

Au, W.W.L., D. A. Carder, R. H. Penner, and B. L. Scronce. 1985. Demonstration of Adaptation in Beluga Whale Echolocation Signals. *Jour. Acoust. Soc. Am.* **77** (2): 726-730.

The echolocation signals of the same beluga were measured first in San Diego Bay and later in Kaneohe Bay, Hawaii, where the ambient noise level was much higher. In Kaneohe Bay, the beluga shifted its signals to higher frequencies and intensities.

Au, W.W.L. and P. W. B. Moore. 1986. The Perception of Complex Echoes by an Echolocating Bottlenosed Dolphin. *Jour. Acoust. Soc. Am.* **80** (Suppl. 1A): S107.

Describes a series of experiments using electronic targets to study how dolphins perceive echoes from targets. Found that dolphins performed like an energy detector with an integration time of 264 us.

Au, W.W.L., P. W. B. Moore, and D. A. Pawloski. 1986. Echolocation Transmitting Beam of the Atlantic Bottlenosed Dolphin. *Jour. Acoust. Soc. Am.* **80**: 688-691.

The transmitting beam patterns of echolocation signals were measured in the vertical and horizontal planes with an array of seven hydrophones.

Au, W.W.L., P. W. B. Moore, and S. W. Martin. 1987. Phantom Electronic Target for Dolphin Sonar Research. *Jour. Acoust. Soc. Am.* **82** (2): 711-713.

A microprocessor-controlled electronic target simulator was developed and used in dolphin echolocation detection experiments. The system captures and stores signals from the dolphin and projects back virtual or "phantom" echoes from replicas of the signals. The system gives the experimenter precise control of target echo characteristics during testing.

Au, W.W.L. 1988. Instrumentation for Dolphin Echolocation Experiments. (Abs.) *Jour. Acoust. Soc. Am.* **83** (Suppl. 1): S15.

Describes instrumentation, developed at NOSC, used in dolphin echolocation experiments and interfaceable with personal computers.

Au, W.W.L. 1988. Sonar Target Detection and Recognition by Odontocetes. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 451-465.

Reviews sonar detection and discrimination experiments conducted in open waters of Kaneohe Bay, Hawaii with bottlenosed dolphins and beluga whales. Discusses experiments to determine capabilities for (1) maximum detection range, (2) target detection in noise, (3) target detection in reverberation, and (4) target recognition and shape discrimination.

Au, W.W.L. 1988. Detection and Recognition Models of Dolphin Sonar Systems. In: *Animal Sonar Processes and Performance,* P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 753-768.

Examines dolphin sonar systems from theoretical and empirical perspectives. Results from a variety of experiments are used to establish the dolphins' sonar operating characteristics. Although humans and dolphins seem to have similar abilities to detect target echoes in noise and to discriminate fine target features, most man-made sonars do not use human auditory capabilities. Dolphins, however, typically use broadband transient-like pulses that are well-matched to their auditory and pattern recognition capacities.

Au, W.W.L., P. W. B. Moore, and D. A. Pawloski. 1988. Detection of Complex Echoes in Noise by an Echolocating Dolphin. *Jour. Acoust. Soc. Am.* **83** (2): 662-668.

"Phantom" echo techniques were used in a series of experiments to investigate how dolphins perceive complex echoes in masking noise. The dolphin performed like an energy detector with an integration time of approximately 264 us.

Au, W.W.L., R. H. Penner, and C. W. Turl. 1988. Propagation of Beluga Echolocation Signals. In: *Animal Sonar Processes and Performance,* P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 47-51.

Discusses a series of measurements made in Kaneohe Bay. The beluga's transmitted beam is slightly narrower than the bottlenosed dolphin's. The transition from near-to-far field occurs within 1 meter of the beluga's snout. The beluga's signal generator is equivalent to a planar circular aperture of about 13 cm.

Au, W.W.L. and D. W. Martin. 1988. Sonar Discrimination of Metallic Plates by Dolphins and Humans. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 809-813.

Digitized broadband echoes from a standard series of metal targets were played to human listeners and discrimination performance was compared with dolphins. Echoes at normal incidence did not seem to contain much useful information for discrimination, but useful cues developed as the incident angle increased. Matched-filter response showed enriched highlight structure at incident angles up to 150 degrees.

Au, W.W.L. and P. W. B. Moore. 1988. The Perception of Complex Echoes by an Echolocating Dolphin. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 295-299.

An echolocating bottlenosed dolphin was required to detect target echoes in noise. Results verified the “phantom echo” technique, estimated a 264 us integration time for the dolphin, and showed that the dolphin’s performance matched that expected for an energy detector.

Au, W.W.L. and J. L. Pawloski. 1988. The Perception of Time-Separation Pitch by Dolphins. (Abstract) *Jour. Acoust. Soc. Am.* **83** (Suppl. 1): S51.

Discusses an experiment in which the capability of a dolphin to perceive the difference between noise with a rippled frequency spectrum and noise with a flat spectrum. Noise with a rippled spectrum is generated by summing broadband noise with its delayed replica. The lower and upper limits of the time-delay used to generate noise stimuli with ripple spectra that can be perceived by a dolphin were determined. Noise with rippled spectrum generate time-separation pitch in the human auditory system. It was suggested that because dolphins can perceive the presence of ripples in the spectrum of noise they may also be able to perceive time-separation pitch.

Au, W.W.L. and J. L. Pawloski. 1989. Detection of Noise with Rippled Spectra by the Atlantic Bottlenosed Dolphin. *Jour. Acoust. Soc. Am.* **86** (2): 591-596.

A dolphin was required to discriminate between rippled and nonrippled underwater noise in three related experiments. The dolphin’s sensitivity was greater for the cos+ than the cos stimuli and greater for delays of 100 us Other results relate the dolphin’s performance to the noise center frequency and suggest that dolphins may perceive time-separation pitch.

Au, W.W.L. and D. W. Martin. 1989. Insights into Dolphin Sonar Discrimination Capabilities from Human Listening Experiments. *Jour. Acoust. Soc. Am.* **86** (5): 1662-1670.

Sonar discrimination experiments with human subjects were compared to dolphin experiments using the same targets. Under laboratory conditions, humans made fine target discriminations about as well as dolphins tested under less controlled conditions. Human subjects generally reported time-domain cues were more useful than frequency-related process in analyzing the echoes.

Au, W.W.L. and L. L. Jones. 1989. Target Strength Measurements of Nets and Implications Concerning Incidental Take of Dall’s Porpoises. (Abs.) Eighth Biennial Conf. on the Biology of Marine Mammals, Pacific Grove, CA., p. 3.

The target strength of some nets used in drift-net and bottom set-net fishing was measured using simulated dolphin sonar signals. The biosonar detection ranges of a monofilament drift-net used in the high-sea salmon mothership fishery were calculated using the sonar equation and detection threshold obtained with *Tursiops truncatus*. It was concluded that echolocating dolphins should be able to detect nets at sufficient ranges to avoid entanglement. Several reasons why entanglement still occurs were suggested.

Au, W.W.L. and D. A. Pawloski. 1989. A Comparison of Signal Detection Between an Echolocating Dolphin and an Optimal Receiver. *Jour. Comp. Physiol.* **A 164**: 451-458.

Dolphin echolocation performance in noise was evaluated in two related experiments using electronic “phantom” targets. The first experiment estimated the echo energy-to-noise ratio at the dolphin’s detection threshold. The second experiment evaluated the dolphin’s receiver operating characteristics in a detection task. Results indicate the dolphin required approximately 7.4 dB higher energy-to-noise ratio than an optimal detector to detect the simulated target.

Au, W.W.L. 1990. Target Detection in Noise by Echolocating Dolphins. In: *Sensory Abilities of Cetaceans*, J. A. Thomas and R. A. Kastelein (eds.). Plenum Press, New York, pp. 203-216.

Reviews dolphin sonar detection experiments in artificial and natural noise conditions. The integration time of the dolphin detection system is discussed. The dolphin detection performance is compared with an energy detector as well as an ideal or optimal receiver.

Au, W.W.L. and D. A. Pawloski. 1990. Cylinder Wall Thickness Difference Discrimination by an Echolocating Dolphin. *Jour. Acoust. Soc. Am.* **88** (Suppl. 1): S4.

Discusses an experiment testing the capability of an echolocating *Tursiops truncatus* to discriminate the differences in the wall thickness of hollow aluminum cylinders in the free field and with artificial noise added. The dolphin could discriminate a wall thickness difference of -0.23 mm and +0.27 mm for a standard wall thickness of 6.35 cm. Back-scatter measurements suggested that if the dolphin used time domain cues, it may be able to detect time differences between two echo highlights within +500 ns. If frequency domain cues were used, the dolphin may be able to detect frequency shifts as small as 3 kHz. If the dolphin used time-separation pitch cues, it may be able to detect differences of 450 Hz.

Au, W.W.L. and P. W. B. Moore. 1990. Critical Ratio and Critical Bandwidth for the Atlantic Bottlenosed Dolphin. *Jour. Acoust. Soc. Am.* **88** (3): 1635-1638.

Critical ratio was measured for a dolphin for frequencies between 30 and 140 kHz. The data below 100 kHz were consistent with previous critical ratio data. Critical bandwidth was also measured at frequencies of 30, 60 and 120 kHz. The critical bandwidth was larger than the critical ratios by 2.2 to 11 times.

Au, W.W.L. and C. W. Turl. 1991. Material Composition Discrimination of Cylinders at Different Aspect Angles by an Echolocating Dolphin. *Jour. Acoust. Soc. Am.* **89** (5): 2448-2451.

Discusses an experiment describing the ability of *Tursiops truncatus* to discriminate a hollow aluminum cylinder from a stainless steel cylinder of the same dimensions at different

target aspect angles. The results indicated that the dolphin could discriminate the aluminum and steel cylinders at an accuracy of 100 percent when the longitudinal axis of the cylinders were oriented perpendicular to the direction of the animal. Performance dropped to a minimum of 80 percent when the longitudinal axis was at a 45-degree aspect angle. Discrimination between the hollow aluminum cylinder and a solid coral cylinder was also tested. The dolphin also discriminated the hollow aluminum and solid coral cylinders almost perfectly at all angles tested.

Au, W.W.L. and L. L. Jones. 1991. Acoustic Reflectivity of Nets: Implications Concerning Incidental Take of Dolphins. *Marine Mammal Science* **7** (3): 258-273.

For a summary, see Au and Jones, 1989.

Au, W.W.L. 1993. *The Sonar of Dolphins*. Springer-Verlag, New York. 277 pp.

First book to summarize research on the physiological, mathematical, acoustical, and engineering aspects of dolphin sonar, the sophisticated and highly sensitive sensory mechanism resulting from millions of years of evolutionary refinement. It continues to be superior to man-made sonar in its ability to recognize and classify targets in noisy environments.

Au, W.W.L., J. L. Pawloski, T.W. Cranford, R.C. Gisiner, and P.E. Nachtigall. 1993. Transmission Beam Pattern of False Killer Whale. (Abs.) *Jour. Acoust. Soc. Am.* **93** (4, Pt. 2): 2358.

Reports on an open-ocean study measuring vertical and horizontal beam patterns of a false killer whale. Reports the major axis of the vertical beam is directed slightly downward. Suggests differences in the fatty structure of the melons of *Pseudorca*, *Tursiops* and *Delphinapterus* could explain differences in elevation angle of their respective vertical beam axes.

Au, W.W.L. and P.E. Nachtigall. 1993. The Effects of Noise on Dolphin Echolocation. (Abs.) *Jour. Acoust. Soc. Am.* **94** (3, Pt. 2): 1829.

Discusses experiments demonstrating target detection and discrimination capabilities of echolocating dolphins can be severely degraded by introduction of masking noise. Reports on changes in signal intensity and frequency by cetaceans to compensate for changes in the ambient noise environment.

Au, W.W.L., J.L. Pawloski, P.E. Nachtigall, T.W. Cranford and R.C. Gisiner. 1993. Echolocation Signals and Transmission Beam Pattern of a False Killer Whale (*Pseudorca crassidens*). (Abs.) Tenth Biennial Conf. on the Biology of Marine Mammals, Galveston, TX, Nov. 11-15.

See Au et al., 1993. above.

Au, W.W.L. 1994. Acoustic Backscatter from a Dolphin. (Abs.) *Jour. Acoust. Soc. Am.* **95** (5, Pt. 2): 2881.

Backscatter measurements were made on a stationary Atlantic bottlenosed dolphin under controlled conditions to determine target strength. Most acoustic energy was reflected from

the area between the dorsal and pectoral fins, corresponding to the location of the dolphin's lungs.

Au, W.W.L. 1994. Acoustics of Echolocating Dolphins and Small Whales. (Abs.) International School of Ethology Workshop, Ettore Majoranna Centre for Scientific Culture, Erice, Sicily, Nov. 4-9.

Discusses echolocation in three species of cetaceans, considering such topics as auditory sensitivity, spectral analysis capabilities, directional hearing, echolocation signals and propagation of those signals from the animals' heads.

Au, W.W.L. 1994. Sonar Detection of Gillnets by Dolphins: Theoretical Predictions.

Rep. Int. Whal. Comm. Special Issue 15, pp. 565-571.

The detection and avoidance of gillnets by echolocating dolphins is examined by using the generalized sonar equation along with target strength values of nets and dolphin sonar detection data. Acoustic reflection data were obtained for several types of nets and associated gear by ensonifying them with simulated bottlenose dolphin sonar signals. The results indicated most dolphins should be able to detect a monofilament gillnet at sufficiently long ranges to avoid entanglement. Reasons for entanglement are discussed.

Au, W.W.L. and P.E. Nachtigall. 1994. Dolphin Acoustics and Echolocation. *Acoustical Bulletin*, August-September Issue, 1994.

General article discussing sound production/reception and other aspects of echolocation in the bottlenose dolphin (*Tursiops truncatus*) and providing data on echolocation capabilities.

Au, W.W.L. 1995. Hot Topics in Animal Bioacoustics. (Abs.). *Jour. Acoust. Soc. Am.* **98** (5, Pt. 2): 2935.

Reports on recent bioacoustics research by the Navy, Air Force and others on a wide variety of species, including insects, birds, terrestrial mammals and whales.

Au, W.W.L., J.L. Pawloski, P.E. Nachtigall, M.E. Blonz, and R.C. Gisiner. 1995. Echolocation Signals and Transmission Beam Pattern of a False Killer Whale (*Pseudorca crassidens*). *Jour. Acoust. Soc. Amer.* **98** (1): 51-59.

The echolocation transmission beam pattern of a false killer whale was measured in the vertical and horizontal planes in the open waters of Kaneohe Bay, Oahu, Hawaii, while the whale performed a target discrimination task. Four types of signals, characterized by their frequency spectra, were measured.

Au, W.W.L., P.E. Nachtigall, and J.L. Pawloski. 1995. The Effects of the Acoustic Thermometry of Ocean Climate Signals on Dolphins and Small Whales. (Abs.). *Jour. Acoust. Soc. Am.* **98** (5, Pt. 2): 2940.

To address concerns of the possible effect of the ATOC signal on marine life, the hearing sensitivities of a false killer whale (*Pseudorca crassidens*) and a Risso's dolphin (*Grampus griseus*) were measured behaviorally.

Au, W.W.L., P.E. Nachtigall and J.L. Pawloski. 1995. The Effects of the ATOC Signals on Dolphins and Small Whales. (Abs.) 11th Biennial Conf. on the Biology of Marine Mammals, p. 5.

See Au, Nachtigall and Pawloski, 1995, above.

Au, W.W.L. 1996. Acoustic Reflectivity of a Dolphin. *Jour. Acoust. Soc. Am.* **99** (6): 3844-3848.

See Au, 1994, above.

Au, W.W.L. and K. Banks. 1996. The Acoustics of Snapping Shrimp in Kaneohe Bay. (Abs.) *Jour. Acoust. Soc. Am.* **99** (4, Pt. 2): 2533.

Reports on study of *Synalpheus paraneomeris*, which are among the major contributors of biological noise in shallow bays, harbors and inlets. Their sounds can severely limit the use of underwater acoustics by humans, dolphins, whales and pinnipeds.

Au, W.W.L. 1997. Some Hot Topics in Animal Bioacoustics. *Jour. Acoust. Soc. Am.* **101** (5, Pt. 1): 2433-2441.

Discusses six bioacoustics studies on a wide variety of species, including two insects, manatees, elephant seals, dolphins and small whales. Notes the increasing interest in and importance of bioacoustics studies.

Au, W.W.L. 1997. Echolocation in Dolphins with a Dolphin-Bat Comparison. *Bioacoustics*. **8**: 137-162.

Discusses the echolocation transmission and reception systems and target detection and discrimination capabilities of bottlenose dolphins, based on three specific experiments. Also provides a brief comparison between the bat and dolphin sonar system, including differences necessitated by substantial differences in the speed of sound through water versus air.

Au, W.W.L. 1997. The Acoustics of Snapping Shrimps. (Abs.) *Jour. Acoust. Soc. Am.* **101** (5, Pt. 2): 3032.

Reports on study of the crustaceans, which are among major contributors of biological noise in shallow waters of temperate and tropical regions. Reports on observation of a new low-frequency precursor signature.

Au, W.W.L. and D.L. Herzing. 1997. Measurement of the Echolocation Signals of the Atlantic Spotted Dolphin *Stenella frontalis* in the Waters off the Grand Bahamas. (Abs.). *Jour. Acoust. Soc. Am.* **101** (5, Pt. 2): 3137-3138.

A three-hydrophone line array with a video camera attached was used to measure the echolocation signals of wild Atlantic Spotted Dolphins. On-axis signals typically had a bimodal spectrum with a low-frequency peak of 45-60 Hz and high-frequency peak at 120-140 kHz.

Au, W.W.L., P.E. Nachtigall and J.L. Pawloski. 1997. Acoustic Effects of the ATOC Signal (75 Hz, 195 dB) on Dolphins and Whales. *Jour. Acoust. Soc. Am.* **101** (5): 1973-1977.

To determine potential acoustic effects of ATOC on dolphins and whales, hearing sensitivity studies were conducted on a false killer whale and a Risso's dolphin. Results indicate that with the source on the axis of the deep sound channel, ATOC signals will probably have minimal physical and physiological effects on cetaceans.

Au, W.W.L. and P.E. Nachtigall. 1997. Acoustics of Echolocating Dolphins and Small Whales. *Marine and Freshwater Physiology and Behavior*. **29**: 127-162.

Discusses the acoustic reception and transmission systems of dolphins, including auditory sensitivity, spectral analysis capabilities, directional hearing, and echolocation signals.

Awbrey, F. T., J. A. Thomas, and R. A. Kastelein. 1988. Low-Frequency Underwater Hearing Sensitivity in Belugas (*Delphinapterus leucas*). *Jour. Acoust. Soc. Am.* **84** (6): 2273-2275.

Sensitivity of three captive belugas was measured at octave intervals between 125 Hz and 8 kHz. Average thresholds at 8 kHz agreed with published data. Sensitivity decreased by approximately 11 dB per octave below 8 kHz.

Bastian, J., C. Wall, and C. L. Anderson. 1966. The Transmission of Arbitrary Environmental Information between Bottlenosed Dolphins. In: *Animal Sonar Systems--Biology and Bionics*, Vol. II, R.G. Busnel (ed.). Laboratoire de Physiologie Acoustique, Jouy-en-Josas 78, France, pp. 803-873.

Bastian, J., C. Wall, and C. L. Anderson. 1968. Further Investigation of the Transmission of Arbitrary Information Between Bottlenosed Dolphins. NUWC TP 109, 40 pp.

The above two papers describe studies designed to ascertain if one dolphin could, by acoustic signals, "tell" another, partitioned from the first, to push one or the other of two paddles. After training, the animals performed correctly, but analysis of recordings indicated that they were responding to self-taught cues, with no comprehension of the task.

Brill, R. L. and P. J. Harder. 1989. The Effects of Sound Attenuation at the Lower Jaw on the Emitted Signals of an Echolocating Dolphin (*Tursiops truncatus*) (Abs.). Eighth Biennial Conf. on the Biology of Marine Mammals, Pacific Grove, CA., p. 8.

See Brill and Harder, 1991, below.

Brill, R. L. and P. J. Harder. 1991. The Effects of Attenuating Returning Echolocation Signals at the Lower Jaw of a Dolphin *(Tursiops truncatus*). *Jour. Acoust. Soc. Am.* **89** (6): 2851-2857.

Reports data indicating that a neoprene hood placed over the lower jaw of a bottlenosed dolphin did not affect the emission of useful echolocation signals and that the dolphin exercised control over click repetition rates and interclick intervals. The results support the theory that echolocation signals are emitted from a site above the line of the gape of the mouth and returning echoes are best received along the lateral sides of the dolphin's lower jaw.

Brill, R.L., J.L. Pawloski, D.A. Helweg, P.W.B. Moore, and W.W.L. Au. 1991. Shape Discrimination and Signal Characteristics of an Echolocating False Killer Whale (*Pseudorca crassidens*). (Abs.) Ninth Biennial Conf. on the Biology of Marine Mammals.

This study demonstrated the false killer whale's ability to discriminate between different targets using biosonar and investigated the whale's emitted signals for changes related to test conditions. The whale's overall performance was comparable to that of echolocating bottlenose dolphins (*Tursiops truncatus*). The data further suggested that the whale relied on cues of target shape and strength, that changes in signal parameters were task related, and that click decreases in click repetition rates were associated with learning experience.

Brill, R.L., J.L. Pawloski, D.A. Helweg, P.W.B. Moore, and W.W. Au . 1991. Target Detection, Shape Discrimination, and Signal Characteristics of an Echolocating False Killer Whale (*Pseudorca crassidens*) (Abs.). Ninth Biennial Conf. on the Biology of Marine Mammals, Chicago, IL, Dec. 5-9, 1991.

See Brill et al., 1991, above.

Brill, R.L., J.L. Pawloski, D.A. Helweg, P.W.B. Moore, and W.W.L. Au. 1992. Target Detection, Shape Discrimination, and Signal Characteristics of an Echolocating False Killer Whale (*Pseudorca crassidens*). *Jour. Acoust. Soc. Am.* **89**:2851-2857.

See Brill et al., 1991, above.

Brill, R.L., J.L. Pawloski, D.A. Helweg, P.W.B. Moore, and W.W.L. Au. 1992. Target Detection, Shape Discrimination, and Signal Characteristics of an Echolocating False Killer Whale (*Pseudorca crassidens*). *Jour. Acoust. Soc. Am.* **92**: 1324-1330.

See Brill et al., 1991, above.

Bullock, T. H., S. H. Ridgway, and N. Suga. 1971. Acoustically Evoked Potentials in Midbrain Auditory Structures in Sea Lions (Pinnipedia). Z. *vergl. Physiologie* **74**: 372-387.

Electrophysiological experiments were conducted to determine neural response to different types of sounds. The results could not settle the question as to whether sea lions employ echolocation, but they indicated lack of specialization for the types of sounds bats and porpoises use.

Bullock, T. H. and S. H. Ridgway. 1972. Neurophysiological Findings Relevant to Echolocation in Marine Animals. In: *Animal Orientation and Navigation*, S.R. Galler et al. (eds). NASA Pub. SP-262, pp. 373-395.

A review.

Bullock, T. H. and S. H. Ridgway. 1972. Evoked Potentials in the Central Auditory System of Alert Porpoises to Their Own and Artificial Sounds. *Jour. of Neurobiology* **3** (1): 79-99.

Among other findings it was noted that high-intensity clicks often evoked quite modest potentials, while a much weaker click gave maximum potentials. This suggested that differences in click composition are quite important to a porpoise.

Caldwell, M. C., D. K. Caldwell, and W. E. Evans. 1966. Sounds and Behavior of Captive Amazon Dolphins, *Inia geoffrensis*. *Contributions in Science*, Los Angeles County Museum, No. 108, 24 pp.

Inia emits pulsed phonations that could be used for echolocation. The freshwater dolphins were not fearful of strange objects (as *Tursiops* usually is) and exhibited curiosity and playfulness.

Carder, D. A. and S. H. Ridgway. 1983. Apparent Echolocation by a Sixty-Day-Old Bottlenosed Dolphin, *Tursiops truncatus*. (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S74.

Squeals were heard about 10 seconds after birth and whistlelike calls soon after, but high-frequency pulses, with head-scanning movements, were not noticed prior to 60 days.

Carder, D. A. and S. H. Ridgway. 1990. Auditory Brainstem Response in a Neonatal Sperm Whale, (*Physeter* spp.) *Jour. Acoust. Soc. Am.* **88** (Suppl. 1): S4.

The auditory brainstem response (ABR) was recorded from suction cup sensors placed on the whale's head. Responses were obtained from clicks with peak frequencies as high as 60 kHz. The characteristics of the whale ABR are described. This is the first such information from any great whale species.

Carder, D., S. Ridgway, B. Whitaker and J. Geraci. 1995. Hearing and Echolocation in a Pygmy Sperm Whale *Kogia*. 11th Biennial Conf. on the Biology of Marine Mammals, Orlando, FL, Dec. 14-18, p. 20.

Reports on study of hearing and echolocation of a beached *Kogia* at the Baltimore Aquarium. Recordings of evoked potential, hearing, and echolocation pulses, including echolocation during pursuit of live fish, showed peak frequencies of 120 to 130 kHz. The hearing assessment was part of a physical exam prior to release back into the Atlantic Ocean. Auditory responses showed sensitivity in the same high-frequency area (100-150 kHz) as the echolocation pulses.

Ceruti, M. G., P. W. B. Moore, and S. A. Patterson. 1983. Peak Sound Pressure Level and Spectral Frequency Distributions in Echolocation Pulses of Atlantic Bottlenosed Dolphins (*Tursiops truncatus*). (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S73.

Peaks in the average bimodal pulse spectrum occurred at 60 and 135 kHz or beyond, while the average unimodal pulse spectrum peaked at 120 kHz. Abstract includes other findings.

Ceruti, M. G., and W. W. L. Au. 1983. Microprocessor-based System for Monitoring a Dolphin's Echolocation Pulse Parameters. *Jour. Acoust. Soc. Am.* **73** (4): 1390-1392.

Describes development of an on-line data acquisition system including a device for measuring the frequency spectrum of transient pulses between 30 and 135 kHz and discusses applications of the system in dolphin echolocation experiments.

Cummings, W. C., P. O. Thompson, and R. C. Cook. 1967. Sound Production of Migrating Gray Whales (*Eschrichtius gibbosus* Erxleben). (Abs.) *Jour. Acoust. Soc. Am.* **44** (5):1211.

Abstract of a paper reporting low-frequency moaning sounds from migrating gray whales.

Cummings, W. C., P. O. Thompson, and R. D. Cooke. 1968. Underwater Sounds of Migrating Gray Whales (*Eschrichtius glaucus* Cope). *Jour. Acoust. Soc. Am.* **44** (5):1278-1281.

Includes methods, results, and discussion of work done on sound production of gray whales. Three categories of sounds range in frequency from 15 to 305 Hz at source levels up to 52 dB re 1 microbar at 1 yard. New findings concerning gray whale behavior are presented.

Cummings, W. C. and L. A. Philippi. 1970. Whale Phonations in Repetitive Stanzas. NUC TP 196, 4 pp.

Recordings of low-frequency sounds from what were probably right whales revealed very similar stanzas lasting 11 to 14 minutes. Stanzas were repeated every 8 to 10 minutes.

Cummings, W. C. and P. O. Thompson. 1971. Underwater Sounds from the Blue Whale (*Balaenoptera musculus*). *Jour. Acoust. Soc. Am.* **50** (4, Pt. 2):1193-1198.

Powerful, three-part sounds lasting about 36.5 seconds and ranging in frequency from 12.5 to 200 Hz were recorded from blue whales off the coast of Chile. Their "moanings," estimated to be 188 dB re 1 u N/m2 (88 dB re 1 ubar) at 1 meter, are the most powerful sustained utterances known from whales or any other living source.

Cummings, W. C., J. F. Fish, P. O. Thompson, and J. R. Jehl, Jr. 1971. Bioacoustics of Marine Animals of Argentina, R/V Hero cruise 71-3. *Antarctic Jour. of the U.S.* **6** (6):266-268.

Describes sounds of cetaceans and pinnipeds recorded along the coast of Argentina.

Cummings, W. C. and J. F. Fish. 1971. Bioacoustics of Cetaceans. Alpha Helix Research Program, 1971, U. of Calif., San Diego, p. 29.

Discusses the likelihood that 20-Hz signals are produced by the blue whale.

Cummings, W. C. and P. O. Thompson. 1971. Gray whales (*Eschrichtius robustus*) Avoid the Underwater Sounds of Killer Whales. *Fish. Bull.* **69** (3):525-530.

Recorded sounds of killer whales were transmitted underwater to gray whales as the latter were migrating south to Baja California. In most instances the gray whales swam away from the sound source. Pure-tone sounds and random noise had no effect.

Cummings, W. C. and P. O. Thompson. 1971. Bioacoustics of Marine Mammals: R/V Hero Cruise 7-3. *Antarctic Jour. of the U.S.* **6** (5): 158-160.

Brief account of the cruise of the NSF research vessel Hero from Punta Arenas to Valparaiso, Chile. Sounds of blue whales as well as South American fur seals and sea lions were recorded. No underwater vocalizations were detected from Guadalupe fur seals.

Cummings, W. C., J. F. Fish, and P. O. Thompson. 1972. Sound Production and Other Behavior of Southern Right Whales (*Eubalaena glacialis*). Trans., San Diego Soc. Nat. Hist. **17** (1):1-13.

The underwater sounds were recorded in Golfo San Jose, Argentina, in late June and early July 1971. The most common was a belch-like utterance with most energy below 500 Hz. The whales also produced two kinds of "moans" and miscellaneous other sounds. Observed behavior suggested bottom feeding.

Diercks, H. J. and W. E. Evans. 1969. Delphinid Sonar: Pulse Wave and Simulation Studies. NUC TP 175, 84 pp.

A series of reports, primarily by Applied Research laboratories, U. of Texas, on analysis of the dolphin's emitted signal forms and simple target-echo forms, and a similar consideration of simulated pulses and their echoes. The data are largely preliminary to more detailed analyses.

Diercks, H. J., R. T. Trochta, C. F. Greenlaw, and W. E. Evans. 1971. Recording and Analysis of Dolphin Echolocation Signals. *Jour. Acoust. Soc. Am.* **49** (6, Pt. 1):1729-1732.

Describes techniques of recording sonar signals by transducers attached by small suction cups to a porpoise's head and body, with examples of data obtained.

Dolphin, W., W.W.L Au, D. Carder, M. Beeler, P.E. Nachtigall, J.L. Palowski and S.H. Ridgway. 1994. Modulation Rate Transfer Functions to Low-Frequency Carriers in Three Species of Cetaceans. *Jour. Acoust. Soc. Am.* **96**:

A new evoked potential technique was developed for hearing testing in *Pseudorca*, *Tursiops*, and *Delphinapterus*.

Evans, E. C. III and K. S. Norris. 1988. On the Evolution of Acoustic Communication Systems in Vertebrates. Part II: Cognitive Aspects. In: *Animal Sonar Processes and Performance*, P.E. Nachtigall and P.W.B. Moore (eds.). Plenum Press, New York, pp.771-681.

Discusses cognitive aspects of acoustic communication as a continuation of Norris and Evans, 1988. The development of processes to bypass innate limitations of the central nervous system is reviewed. Communication heirarchies and cognitive aspects of language and echolocation are also reviewed.

Evans, W. E. 1967. Vocalization Among Marine Mammals. In: *Marine Bio-Acoustics*, Vol. II, W.H. Tavolga (ed.). Pergamon Press, Elmsford, NY, pp. 159-186.

An account of the kinds of sounds produced by marine mammals with discussion of what is known regarding their significance.

Evans, W. E. 1967. Discussion of Mechanisms of Overcoming Interference in Echolocating Animals, by A. D. Grinnell. In: *Animal Sonar Systems--Biology and Bionics*, Vol. 1. R. G. Busnel (ed.). Laboratoire de Physiologie Acoustique, Jouy-en-Josas 78, France, pp. 495-503.

Discusses some of the possible interference factors in biological echolocation in the aquatic environment.

Evans, W. E. and B. A. Powell. 1967. Discrimination of Different Metallic Plates by an Echolocating Delphinid. In: *Animal Sonar Systems--Biology and Bionics*, Vol. 1. R. G. Busnel (ed.). Laboratoire de Physiologie Acoustique, Jouy-en-Josas 78, France, pp. 366-383.

A blindfolded bottlenosed dolphin was found to be capable of discriminating a 30-cm diameter target (paddle) of 0.22-cm copper plate with echolocation when paired with targets of other materials, including aluminum plate.

Evans, W. E. and J. Bastian. 1969. Marine mammal communication: social and echological factors. In: *The Biology of Marine Mammals*, H. T. Andersen (ed.). Academic Press, San Diego, CA, pp. 425-475.

While many sounds made by marine mammals have social and communicative significance, there is no evidence porpoises (regarding which there has been much speculation) possess a language comparable to the human language.

Evans, W. E. 1973. Echolocation by Marine Delphinids and One Species of Freshwater Dolphin. *Jour. Acoust. Soc. Am.* **S4** (1): 191-199.

A brief summary of the state of knowledge of echolocation of small-toothed whales.

Evans, W. E. and P. F. A. Maderson. 1973. Mechanisms of Sound Production in Delphinid Cetaceans: A Review and Some Anatomical Considerations. *Amer. Zool.* **13**:1205-1213.

Review of earlier literature describing possible sites of sound-producing mechanisms, with a discussion of the morphology of the nasal sac system. It is concluded that theories implicating the nasal sac system in sound production are supported by certain anatomical specializations adjacent to the tissues of this system.

Fish, J. F. and H. E. Winn. 1969. Sounds of Marine Mammals. In: *Encyclopedia of Marine Resources*, F. E. Firth (ed.). Van Nostrand Reinhold Co., New York, pp. 649-655.

Summarizes important contributions to the knowledge of marine mammal sound production and hearing. Includes the major papers up to 1967.

Fish, J. F. and J. S. Vania. 1971. Killer Whale (*Orcinus orca*) Sounds Repel White Whales. *Fish. Bull.* **69** (3):531-535.

A study conducted to determine if white whales migrating up the Kvichak River in Alaska which feed on salmon smolt could be turned back by underwater transmission of killer whale sounds. The playback of killer whale sounds was found to be an effective way to keep white whales out of the river.

Fish, J. F., J. L. Sumich, and G. E. Lingle. 1974. Sounds Produced by the Gray Whale (*Eschrichtius robustus*). *Mar. Fish. Rev.* **36** (4): 38-48.

Describes the sounds recorded from a young gray whale in captivity and sounds recorded in the vicinity of the whale when it was returned to the ocean.

Fish, J. F., C. S. Johnson, and D. K. Ljungblad. 1976. Sonar Target Discrimination by Instrumented Human Divers. *Jour. Acoust. Soc. Am.* **S9** (3):602-606.

Human divers, instrumented with “bionic” sonar equipment based on the porpoise echolocation system and presented with targets earlier used in porpoise sonar discrimination experiments, made scores as good as or better than the porpoises.

Fish, J. F. and C. W. Turl. 1976. Acoustic Source Levels of Four Species of Small Whales. NUC TP 547, 14 pp.

Absolute sound pressure level measurements were made at sea on herds of the common dolphin, pilot whale, bottlenosed dolphin, and northern right whale.

Floyd, R. W. 1980. Models of Cetacean Signal Processing. In: *Animal Sonar Systems*, R.G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 616-623.

A review in which the apparent merits and deficiencies of various models of signal processing are discussed, with suggestions for future experiments.

Floyd, R. W. 1988. Biosonar Signal Processing Applications. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 773-783.

The performance of some existing man-made sonars and dolphin sonar is compared. The differences between the two are discussed and methods for improving man-made sonars are described.

Floyd, R. W. and J. E. Sigurdson. 1996. Autonomous Detection and Classification of

Bottom Objects with Multi-Aspect Sonar. Symposium on Technology and the Mine Problem, U. S. Naval Postgraduate School, Monterey, CA.

Describes test of a mobile 40-beam multiple-aspect sonar on a VSW field with many small bottom-targets. Novel automated signal analysis methods successfully detected all targets with a very low false-alarm rate and extracted a file of multiple-aspect echo returns for each target. Classification of detected targets was based on highlight separations and distributions of reflected energy.

Friedl, W. A. and P. O. Thompson. 1981. Measuring Acoustic Noise Around Kahoolawe Island. (Abs.) *Jour. Acoust. Soc. Am.* **70** (Suppl. 1): S84.

Seven sonobuoys were monitored for seven hours from a P-3 aircraft during gunnery exercises by a Navy ship north of Kahoolawe. Humpback whale locations and behavior were also monitored. Whales were observed swimming, lying still, diving, surfacing, breeching, and bobtailing. Movements and activities of the whales could not be related to any airborne, surface, or subsurface stimuli.

Friedl, W. A. and P. O. Thompson. 1981. Measuring Acoustic Noise Around Kahoolawe Island. NOSC TR 732, 15 pp.

See Friedl and Thompson, 1981, above.

Gales, R. S. 1966. Pickup, Analysis, and Interpretation of Underwater Acoustic Data. In: *Whales, Dolphins, and Porpoises*, K. S. Norris (ed.). Univ. of Calif. Press, Berkeley.

Discusses instrumentation used for recording underwater sounds and presents analyses of a variety of cetacean sounds.

Gales, R. S., S. E. Moore, W. A. Friedl, and J. Rucker. 1987. Effects of Noise of a Proposed Ocean Thermal Energy Conversion Plant on Marine Animals--A Preliminary Report. (Abs.) *Jour. Acoust. Soc. Am.* **82** (Suppl. 1): S98.

Discusses likely perception and behavioral responses of cetaceans and fishes to predicted noise from a 40-Mw. OTEC plant on Oahu, Hawaii.

Green, R. F., S. H. Ridgway, and W. E. Evans. 1980. Functional and Descriptive Anatomy of the Bottlenosed Dolphin Nasolaryngeal System with Special Reference to the Musculature Associated with Sound Production. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 199-238.

Detailed anatomical information with reference to external landmarks to facilitate the use of electromyographic techniques in determining activity of specific muscles used in sound production.

Green, D.M., H. DeFerrari, D. McFadden, J. Pearse, A. Popper, W.J. Richardson, S.H. Ridgway and P. Tyack. 1994. Low-Frequency Sound and Marine Mammals: Current Knowledge and Research Needs. Ocean Studies Board, Commission on Geosciences, Environment, and Resources, National Research Council, Washington, DC, 97 pp.

This report evaluates potential threats to marine mammals from low-frequency sound in the ocean. Suggestions are made for research to answer questions of environmental concern.

Hall, J. D. and C. S. Johnson. 1972. Auditory Thresholds of a Killer Whale (*Orcinus orca*) Linnaeus. *Jour. Acoust. Soc. Am.* **51**(2, Pt. 2): 515-517.

Using operant conditioning techniques, an audiogram was obtained for a killer whale for frequencies between 500 Hz and 31 kHz. Greatest sensitivity was observed at 15 kHz, with upper limit of hearing at 32 kHz.

Hammer, C. E. and W. W. L. Au. 1978. Target Recognition via Echolocation by an Atlantic Bottlenosed Dolphin (*Tursiops truncatus*). (Abs.) *Jour. Acoust. Soc. Am.* **64** (Suppl. 1): S87.

Target-recognition behavior as a function of target composition and internal structure was investigated using cylindrical hollow aluminum and solid coral rock targets for baseline data. Experiments were then conducted to determine the critical characteristic for target recognition.

Hammer, C. E. and W. W. L. Au. 1980. Porpoise Echo-recognition: An Analysis of Controlling Target Characteristics. *Jour. Acoust. Soc. Am.* **68** (5):1285-1293.

After baseline performance was established, a two-alternative, forced-choice method was used with two hollow aluminum and two coral rock cylinders (standard targets) probe targets. The probe target results indicated that the bottlenosed dolphin had learned to recognize the echo characteristics of the aluminum standards and differentiated other targets on that basis.

Harley, H.E., M.J. Xitco, and H.L. Roitblat. 1995. Echolocation, Cognition and the Dolphin's World. In: *Sensory Systems of Aquatic Mammals*, R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds.). DeSpil Publishers, Woerden, The Netherlands.

Discusses studies investigating the flexibility with which a dolphin can use echoic information. Studies suggest a pair of dolphins can share object information received through a single set of echoes. The flexibility of such representations may impact delphinid social behavior.

Harley, H., H.L. Roitblat, and P.E. Nachtigall. 1996. Object Representation in the Bottlenosed Dolphin (*Tursiops truncatus*): Integration of Visual and Echoic Information. *Jour. Exper. Psych.: Animal Behavior Processes*. **22** (2), 164-174.

A dolphin performed a 3-alternative matching-to sample task in different modality conditions. The dolphin successfully matched familiar objects in the cross-modal (vision-echolocation, echolocation-vision) conditions, suggesting that the dolphin has an object-based representational system.

Helweg, D.A., H.L. Roitblat, and P.E. Nachtigall. 1993. Object Constancy in Dolphin Echolocation. (Abs.). Tenth Biennial Conf. on the Biology of Marine Mammals, Society for Marine Mammalogy, Galveston, TX, Nov. 12-16.

Examines dolphin representation of objects they echolocate. Discusses experiment to investigate whether they construct an aspect-independent cognitive representation containing structural (shape) information or an acoustically based one from echoes.

Helweg, D.A., H.L. Roitblat, P.E. Nachtigall, W.W.L. Au, and R.J. Irwin. 1996. Discrimination of Echoes from Aspect Dependent Targets by a Bottlenose Dolphin and Human Listeners. In: *Sensory Systems of Aquatic Mammals*, R. A. Kastelein, J.A. Thomas, and P.E. Nachtigall (eds.). pp. 129-136.

Aspect-dependent targets (such as cubes) produce different echoes at different orientations, which may impede recognition. This study suggests an Atlantic bottlenose dolphin may have formed aspect-invariant representations of targets, rather than representations of the specific acoustic qualities of the echoes. This may require integration of changes in echo characteristics such as amplitude across successive echoes.

Helweg, D.A., W.W.L. Au, H.L. Roitblat and P.E. Nachtigall. 1996. Acoustic Basis for Recognition of Aspect-Dependent Three-Dimensional Targets by an Echolocating Bottlenose Dolphin. *Jour. Acoust. Soc. Am.* **99** (4): 2409-2420.

A blindfolded Atlantic bottlenose dolphin (*Tursiops truncatus*) learned to match aspect-dependent three-dimensional targets (such as cubes) at haphazard orientations, although with some difficulty. Results suggested that the dolphin recognized the targets using a multidimensional representation containing amplitude and spectral information and that dolphins can form stable representations of targets regardless of orientation based on varying sensory properties.

Helweg, D.A., H.L. Roitblat, P.E. Nachtigall and M.J. Hautus. 1996. Recognition of Aspect-Dependent Three-Dimensional Objects by an Echolocating Atlantic Bottlenose Dolphin. *Jour. Exper. Psych.*: *Animal Behavior Processes*. **22**: 19-31.

The study examined the ability of an echolocating bottlenose dolphin (*Tursiops truncatus*) to recognize aspect-dependent objects, such as cubes, which produce acoustically different echoes at different orientations. The dolphin recognized the objects even though they were free to rotate and sway. The results show dolphins can use varying acoustic properties to recognize constant objects and suggest that aspect-independent representations may be formed by combining information gleaned from multiple echoes.

Herald, E. S. 1969. A Field and Aquarium Study of the Blind River Dolphin (*Platanista gangetica*). NUC TP 153, 62 pp.

Blind river dolphins ("susu") from the Indus River of Pakistan swim on their sides. Presumably this permits a lateral echolocation sweep of the bottom. Underwater sound emissions of pulse trains are produced continuously.

Jacobs, D. W. and J. D. Hall. 1972. Auditory Thresholds of a Freshwater Dolphin (*Inia geoffrensis*). Blainville. *Jour. Acoust. Soc. Am.* **51** (2, Pt. 2):530-533.

An Amazon River dolphin was conditioned to respond to pure tones by pushing a lever. By this method an audiogram was obtained for frequencies between 1.0 and 105 kHz. Greatest sensitivity was found between 75 and 90 kHz, with effective upper limit of hearing at 105 kHz.

Johnson, C. S. 1967. The Possible Use of Phase Information in Target Discrimination, and the Role of Pulse Rate in Porpoise Echoranging. In: *Animal Sonar Systems--Biology and Bionics*, Vol. 1, R. G. Busnel (ed.). Laboratoire de Physiologie Acoustique Jouy-en-Josas 78, France, pp. 384-398.

A discussion of the paper by Evans and Powell, 1967. On the basis of theoretical considerations there are phase differences in reflected pulse shapes which may be utilized by the porpoise. An analysis of pulse rate versus range and time indicates the decreasing pulse rate is based on time before target contact rather than range.

Johnson, C. S. 1968. Sound Detection Thresholds in Marine Mammals. In: *Marine Bio-Acoustics*, Vol. 2, W. N. Tavolga (ed.). Pergamon Press, Elmsford, NY, pp.247-260.

By a behavioral response method, an audiogram for a bottlenosed porpoise was obtained over a frequency range from 75 Hz to 150 kHz. Maximum sensitivity was found at about 50 kHz.

Johnson, C. S. 1968. Relation Between Absolute Threshold and Duration-of-Tone Pulses in the Bottlenosed Porpoise. *Jour. Acoust. Soc. Am.* **43** (4):757-763.

This study indicated that the porpoise, in detecting pure tone stimuli, integrated the acoustic energy in essentially the same way that humans do.

Johnson, C. S. 1969. Masked Tonal Thresholds in the Bottlenosed Porpoise. *Jour. Acoust. Soc. Am.* **44** (4): 965-967.

An analysis of hearing thresholds when a narrowband of frequencies is masked by broadband noise.

Johnson, C. S. 1971. Auditory Masking of One Pure Tone by Another in the Bottlenosed Porpoise. *Jour. Acoust. Soc. Am.* **49** (L): 1317.

Pure-tone masking-tone thresholds were obtained for a bottlenosed porpoise. Using a masking-tone frequency of 70 kHz and masking levels at 40 and 80 dB above threshold, the shapes of the masking curves were similar to those obtained from human subjects at much lower frequencies.

Johnson, C. S. 1979. Thermal-noise Limit in Delphinid Hearing. NOSC TD 270, 4 pp.

In quiet tanks, thermal noise is the dominant sound source above 50 kHz. Evidence indicates that in the frequency range above 50 kHz cetacean auditory thresholds are limited by thermal noise.

Johnson, C. S. 1980. Important Areas for Future Cetacean Auditory Study. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 515-518.

Discusses three apparent anomalies in experimental results on cetacean hearing.

Johnson, C. S. 1986. Dolphin Audition and Echolocation Capacities. In: *Dolphin Cognition and Behavior,* R. J. Schusterman, J. A. Thomas, and F. G. Wood (eds.). Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 115-136.

A review. Includes ear anatomy and transduction mechanisms, auditory thresholds, echolocation sound production, and theoretical echolocation models.

Johnson, C. S. 1988. A Brief History of Bionic Sonars. In: *Animal Sonar Processes and Performances,* P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 769-771.

A brief description of the U.S. Navy's attempts to build bionic sonars.

Johnson, C. S., M. W. McManus, and D. Skaar. 1989. Masked Tonal Hearing Thresholds in the Beluga Whale. *Jour. Acoust. Soc. Am.* **85** (6): 2651-2654.

Beluga critical ratios were about 3 dB lower than those reported for bottlenosed dolphins. Reported critical ratios for dolphins are not significantly different from beluga ratios at higher frequencies.

Johnson, C. S. 1991. Hearing Thresholds for Periodic 60-Hz Tone Pulses in the Beluga Whale. *Jour. Acoust. Soc. Am.* **89** (6): 2996-3001.

Masked thresholds were measured with various pulse lengths and repetition times. Unlike the human data, the whales' integration times were found to vary almost directly with time.

Johnson, R. A. 1980. Energy Spectrum Analysis in Echolocation. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish, (eds.). Plenum Press, New York, pp. 673-693.

Discusses object detection, distance estimation, and object identification and how they may be accomplished in energy spectrum analysis as an alternative to correlation processing in the time-domain sense.

Johnson, R. A., P. W. B. Moore, M. W. Stoermer, J. L. Pawloski, and L. C. Anderson. 1988. Temporal Order Discrimination within the Dolphin Critical Interval. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 317-322.

Reports results on experiments to determine the ability of a dolphin to detect the difference in arrival order for appropriate stimuli and investigate the cues available to discriminate the stimuli. This paper concludes that the dolphin has the ability to discriminate the temporal order of click-pairs within the critical interval, and although the analysis in the time domain might explain this ability, the results support the hypothesis that the analysis of rippled spectra may be an important function of dolphin audition.

Kadane, J., R. H. Penner, W. W. L. Au, and R. W. Floyd. 1980. Microprocessors in Collection and Analysis of *Tursiops truncatus* Echolocation Data. (Abs.) *Jour. Acoust. Soc. Am.* **68** (Suppl. 1): S8.

Describes the equipment used to collect and analyze a variety of parameters of echolocation signals emitted by a dolphin in various detection tasks.

Kadane, J, and R. H. Penner. 1983. Range Ambiguity and Pulse Interval Jitter in the Bottlenosed Dolphin. *Jour. Acoust. Soc. Am.* **74** (3): 1059-1061.

In pulse-mode sonar systems which use range gating, range ambiguity can be caused by echoes from objects at multiple distances returning simultaneously. A bottlenosed dolphin was found to vary consecutive interpulse intervals enough to eliminate this form of range ambiguity.

Lammers, M.O. and W.W.L. Au. 1996. Broadband Recording of Social Acoustic Signals of the Hawaiian Spinner and Spotted Dolphins. (Abs.). *Jour. Acoust. Soc. Am.* **100** (4, Pt. 2): 2609.

Signals from Hawaiian spinner and spotted dolphins up to 55 kHz in frequency were recorded using a new technique. Digitizing signals directly into a laptop computer through an analog/digital converter allowed recording and study of sonic and ultrasonic components of the whistles and burst pulses of the dolphins.

Lang, T. G. and H. A. P. Smith. 1965. Communication Between Dolphins in Separate Tanks by Way of an Acoustic Link. *Science* **150**:1839-1843.

Alternating exchange of different kinds of whistles occurred between two dolphins.

Leatherwood, J. S., R. A. Johnson, D. K. Ljungblad, and W. E. Evans. 1977. Broadband Measurements of Underwater Acoustic Target Strengths of Panels of Tuna Nets. NOSC TR 126, 18 pp.

Target strengths of sample panels of tuna nets of three different mesh sizes were determined. All panels produced sufficiently strong returns to allow porpoises to detect them acoustically.

Ljungblad, D. K. and J. S. Leatherwood. 1979. Sounds Recorded in the Presence of Adult and Calf Bowhead Whales (*Balaena mysticetus*). NOSC TR 420, Rev. 1, 108 pp.

Low-frequency sounds, identified as Type A and Type B, were recorded. Type A sounds were of brief duration, with fundamental frequency ranging from 50 to 580 Hz and few or no harmonics. Type B sounds were longer, the fundamental frequency ranged from 100 to 195 Hz, and they were rich in harmonics.

Ljungblad, D. K., J. S. Leatherwood, and M. E. Dahlheim. 1980. Sounds Recorded in the Presence of an Adult and Calf Bowhead Whale. *Mar. Fish. Rev.* **42**(9-10):86-87.

Modified version of Ljungblad and Leatherwood, 1979.

Ljungblad, D. K., P. D. Scoggins, and W. G. Gilmartin. 1982. Auditory Thresholds of a Captive Eastern Pacific bottlenosed Dolphin, *Tursiops* spp. *Jour. Acoust. Soc. Am.* **72** (6):1726-1729.

Hearing thresholds were tested using behavioral response techniques. The animal responded to signals ranging from 2 to 135 kHz, but not to higher frequencies. Range of greatest sensitivity was between 25 and 70 kHz, with peak sensitivities at 25 and 50 kHz.

Ljungblad, D. K., P. O. Thompson, and S. E. Moore. 1982. Underwater Sounds Recorded from Migrating Bowhead Whales (*Balaena mysticetus*) in 1979. *Jour. Acoust. Soc. Am.* **71** (2):477-482.

Sounds were recorded from sonobuoys during spring and fall migrations. Most sounds at both times were low-frequency (below 800 Hz) moans, simple or complex. Repetitive sequences were found only in the spring samples. High-frequency (to 4 kHz) trumpeting calls were recorded in the fall (but also occurred in the spring of 1981).

Marten, K., K. S. Norris, P. W. B. Moore, and K. A. Englund. 1988. Loud Impulse Sounds in Odontocete Predation and Social Behavior. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore, (eds.). Plenum Press, New York, pp. 567-579.

This paper discusses analysis of data to determine the extent of impact on loud impulse sounds during fish predation by odontocetes. The characteristics and source of impulse sounds are also discussed.

Martin, D. W. and W. W. L. Au. 1980. Aural Discrimination of Target Echoes in White Noise by Human Observers Using Broadband Sonar Pulses. (Abs.) *Jour. Acoust. Soc. Am.* **68** (Suppl. 1): 557.

Recordings of target echoes obtained from dolphin-like pulses directed at hollow aluminum and glass cylinders and one solid aluminum cylinder were played back to human subjects at 1/50 of the original rate. The average 75 percent correct response threshold occurred at different signal-to-noise ratios, with the lowest SNR for the solid target.

Martin, D. W. and W. W. L. Au. 1983. Auditory Detection of Broadband Sonar Echoes from a Sphere in White Noise. (Abs.) *Jour. Acoust. Soc. Am.* **73** (Suppl. 1): 591.

The ability of two human subjects to detect time-stretched broadband sonar echoes from a water-filled stainless-steel sphere in white noise was tested. At stretch factors of 75 and 50, the subjects performed better than dolphins did with unaltered echoes.

Martin, D. W. and W. W. L. Au. 1986. Broadband Sonar Classification Cues: An Investigation. NOSC TR 1123, 36 pp.

Sonar echo-discrimination experiments were conducted with human subjects to (1) measure their performance using echoes from geometric targets, (2) determine the acoustic cues used, (3) develop software algorithms to extract echo features similar to those used by humans, and (4) determine whether the features can be used for automatic target classification.

Martin, D. W. and W. W. L. Au. 1988. An Automatic Target Recognition Algorithm Using Time-Domain Features. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 829-833.

A technique to recognize broadband echoes from underwater targets is discussed. The technique used the envelope of the time-domain echoes with the time between highlights and the relative amplitude of highlights being the features used to describe targets. The ability of this technique to separate target echoes was tested for a noise-free condition and was found to perform well.

McCormick, J. G., E. G. Wever, J. Palin, and S. H. Ridgway. 1971. Sound Conduction in the Dolphin Ear. *Jour. Acoust. Soc. Am.* **48** (6):1418-1428.

By electrophysiological methods, the mechanisms and pathways of sound conduction in the dolphin ear were determined.

McCormick, J. G. E. G. Wever, S. H. Ridgway, and J. Palin. 1980. Sound Reception in the Porpoise as it Relates to Echolocation. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 449-467.

A review of earlier work, with the addition of new information and arguments.

Moore, P. W. B. 1975. Underwater Localization of Click and Pulsed Pure-tone Signals by the California Sea Lion (*Zalophus californianus*). *Jour. Acoust. Soc. Am.* **57** (2): 406-410.

The ability of the sea lion to localize both pure tone and click sounds underwater is presented. The results are compared to previous studies on sea lions and seals.

Moore, P. W. B. and W. W. L. Au. 1975. Underwater Localization of Pulsed Pure Tones by the California Sea Lion (*Zalophus californianus*). *Jour. Acoust. Soc. Am.* **58** (3): 721-727.

The animal appeared to use time-difference cues for lower frequencies (0.5-16 kHz) and intensity-difference cues for higher frequencies (4-16 kHz). The minimum auditory angles for the lower frequencies were smaller than for the higher frequencies.

Moore, P. W. B. and R. J. Schusterman. 1977. Discrimination of Pure-Tone Intensities by the California Sea Lion. *Jour. Acoust. Soc. Am.* **60** (6):1405-1407.

The ability of the sea lion to discriminate tonal intensities was measured and compared to other mammals. The role of sound intensity difference in sea lion localization is also discussed. The experiment was directed at determining a theoretical ability suggested by earlier sea lion localization studies.

Moore, P. W. B. and R. J. Schusterman. 1978. Masked Pure Tone Thresholds of the Northern Fur Seal (*Callorhinus ursinus*). *Jour. Acoust. Soc. Am.* **64** (Suppl. 1A): S87.

Thresholds for two animals were determined at three continuous broadband masked noise levels at 2, 4, 8, 16 and 32 kHz. The critical ratio for both animals was calculated.

Moore, P. W. B. 1980. Cetacean Obstacle Avoidance. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 97-108.

A review, including early dolphin echolocation experiments and field observations.

Moore, P. W. B. and W. W. L. Au. 1981. Directional Hearing Sensitivity of the Atlantic Bottlenosed Dolphin (*Tursiops truncatus*) in the Vertical Plane. (Abs.) *Jour. Acoust. Soc. Am.* **70** (Suppl. 1): 585.

Maximum sensitivity for pure-tone frequencies of 30, 60, and 120 kHz occurred between 5 and 10 degrees above the midline of the mouth. Sensitivity dropped more sharply with increasing angle above the midline rather than below.

Moore, P. W. B., and W. W. L. Au. 1982. Masked Pure-Tone Thresholds of the Bottlenosed Dolphin (*Tursiops truncatus*) at Extended Frequencies. (Abs.) *Jour. Acoust. Soc. Am.* **70** (Suppl. 1): 542.

Response thresholds at two masking noise levels were obtained from 30 to 140 kHz. The critical ratio (CR), ratios of signal power to noise spectrum level, was calculated for both noise levels. A function relating CRs to frequency conformed with previous finding to 100 kHz, but results above 100 kHz, not previously determined, showed a sharp increase at 110 kHz, followed by a decline at 120 kHz.

Moore, P. W. B. and S. A. Patterson. 1983. Behavioral Control of Echolocating Source Level in the Dolphin (*Tursiops truncatus*). Fifth Annual Conf. on the Biology of Marine Mammals, Boston, MA. **70** (4).

This report covers the training steps designed to teach a dolphin to generate echolocation signals that vary in frequency content and amplitude.

Moore, P. W. B. and W. W. L. Au. 1983. Critical Ratio and Bandwidth of the Atlantic Bottlenosed Dolphin (*Tursiops truncatus*). (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): 573.

Masked underwater pure-tone thresholds were obtained at test frequencies ranging from 30 to 140 kHz at two levels of broadband noise.

Moore, P. W. B., R. W. Hall, W. A. Friedl, and P. E. Nachtigall. 1984. The Critical Interval in Dolphin Echolocation: What is it? *Jour. Acoust. Soc. Am.* **76** (1): 314-317.

In an active echolocation target detection task, the echolocation click from a bottlenosed dolphin triggered a short-sound-burst masking noise, from the target area, which could be adjusted from coincidence with the target echo to delays up to 700 ms. The animal's detection performance, high at long delays, dropped to chance level for a 100-ms delay. This was seen as supporting the view that time separation pitch may be an analytic mechanism used by the dolphin to discern within-echo target attributes rather than for determining target range.

Moore, P. W. B. and D. A. Pawloski. 1987. Voluntary Control of Peak Frequency in Echolocation Emissions of Dolphin (*Tursiops truncatus*). (Abs.) Seventh Biennial Conf. on the Biology of Marine Mammals. Society of Marine Mammalogy, Miami, FL., p. 47.

Discusses experiments with a bottlenosed dolphin previously trained to shift its outgoing emitted source level and also trained to shift the peak frequency of its echolocation emissions.

Moore, P. W. B. and R. J. Schusterman. 1987. Audiometric Assessment of Northern Fur Seals (*Callorhinus ursinus*). *Marine Mammal Science* **3**: 31-53.

The hearing thresholds for the Alaska fur seal in both air and underwater are presented and compared to other pinnipeds. This study defines hearing in fur seals.

Moore, P. W. B. 1988. Dolphin Echolocation and Audition. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 161-168.

A review of psychoacoustic data on bottlenosed dolphins presented or collected from 1980 to 1988, including data on critical interval, echolocation adaptability, and basic hearing parameters. Recommendations for future research are also outlined.

Moore, P. W. B. 1989. Investigations on the Control of Echolocation Pulses in the Dolphin. Fifth International Theriological Congress, Rome, Italy, August 22-29, 1989.

See Moore and Pawloski, 1990, below.

Moore, P. W. B. and D. A. Pawloski. 1990. Investigations on the Control of Echolocation Pulses in the Dolphin. In: *Dolphin Sensory Processes*, J.A. Thomas and R. Kastelein (eds.). Plenum Press, New York, pp. 305-316.

Summarizes a series of experiments to determine if the echolocation emission parameters of the dolphin were under voluntary control. The ability of the dolphin to control the source level and frequency content of the echolocation emission is discussed. Results from several experiments are presented.

Moore, P. W. B. 1991. Dolphin Psychophysics: Concepts for the Study of Dolphin Echolocation. In: *Dolphin Societies: Methods of Study*, K. Pryor and K. Norris (eds.). Univ. of Calif. Press, Berkeley.

A compendium of personal insights on the study of dolphin sensory systems along with basic explanations of the tools and techniques used to study dolphins.

Moore, P. W. B. 1991. Dolphin Psychophysics: Concepts for the Study of Dolphin Echolocation. In: *Dolphin Societies: Discoveries and Puzzles,* K. Pryor and K. Norris (eds.). University of California Press, Berkeley and Los Angeles, pp.365-382.

A chapter discussing various applications of traditional psychoacoustics procedures for exploring the dolphin's echolocation capability.

Moore, P. W. B., P.E. Nachtigall, and H.L. Roitblatt. 1992. Classification of Biological Echolocation Signals. In: NRaD TD 2412, IR-IED 1992 Annual Report, p. 27-41.

A report of a three-year effort to develop and model the dolphin's echolocation strategy and target classification capability based on a match-to-sample discrimination paradigm.

Moore, P.W.B. and D.A. Pawloski. 1993. Interaural Time Discrimination in the Bottlenose Dolphin (Abs.) *Jour. Acoust. Soc. Am.* **94** (3, Pt. 2): 1829.

Reports on first behavioral measurements on interaural hearing abilities in the dolphin (*Tursiops truncatus*). Special "jawphones" were constructed to act as earphones to isolate and present signals to the dolphin. Results suggested the dolphin has a keen ability to discriminate interaural time differences, with capabilities superior to any mammal previously measured.

Moore, P.W.B, D.A. Pawloski, and L. Dankiewicz. 1995. Interaural Time and Intensity Difference Thresholds in the Bottlenose Dolphin (*Tursiops truncatus*). In: *Sensory Systems of Aquatic Mammals*, R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds). De Spil, Woerden, Netherlands, pp.11-24.

The first measures of interaural hearing parameters for any marine mammal. Thresholds for interaural time and intensity differences are reported. Results indicate the dolphin is superior to land mammals in discriminating on-going time disparity and slightly better than humans in determining interaural intensity differences. Best frequencies for both thresholds occur at least one order of magnitude above traditionally reported thresholds.

Moore, P.W.B. and L.W. Bivens. 1995. The Bottlenose Dolphin: Nature’s ATD in SWMCM Autonomous Sonar Platform Technology. Autonomous Vehicles in Mine Countermeasures Symposium. Naval Postgraduate School, Monterey, CA, April 4-7, 1995.

Marine mammal systems of the Navy are discussed, including issues relating to the Navy's current and future plans for fleet enhancements.

Moore, S. E., D. K. Ljungblad, and D. R. Schmidt. 1984. Ambient, Industrial and Biological Sounds Recorded in the Northern Bering, Eastern Chukchi and Alaskan Beaufort Seas During the Seasonal Migrations of the Bowhead Whale (*Balaena mysticetus*) 1979-1982. SEACO, Inc. Report for the Minerals Management Service, U. S. Dept. Interior, 104 pp.

Recordings made during spring and fall bowhead whale migration were analyzed for ambient, industrial, and biological sound content. The effect of sea state, ice covering and depth on measured ambient levels indicates that sea state was the dominant correlate. When corrected for distance, highest industrial noise levels were measured from seismic airguns followed by pipe driving, large vessels, small vessels and aircraft. Seven bowhead and four gray whale call types are presented. Beluga and bearded seal sounds were also analyzed.

Moore, S.E. and S.H. Ridgway. 1995. Whistles Produced by Common Dolphin from the Southern California Bight. *Aquatic Mammals*. **21**(1): 55-63.

Compares the whistles of two common dolphins, *Delphinus delphis*, kept in San Diego with those of a wild herd of the same species off Southern California.

Moore, S. E. and S. H. Ridgway. 1996. Patterns of Dolphin Sound Production and Ovulation. *Aquatic Mammals*. **22** (3): 175-184.

Sound production in two female common dolphins, *Delphinus delphis*, decreased during times when plasma progesterone levels were high concurrent with ovulation. It is suggested that total sound production might be useful in monitoring reproductive cycles.

Murchison, A. E. 1980. Detection Range and Range Resolution of Echolocating Bottlenosed Porpoise (*Tursiops truncatus*). In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 43-70.

The maximum detection ranges of two *Tursiops* were determined for two different spherical targets in open water. A third target was used to determine the effects of target depth (or nearness to the bottom) at maximum detection ranges.

Nachtigall, P. E., A. E. Murchison, and W. W. L. Au. 1978. Cylinder and Cube Shape Discrimination by an Echolocating Blindfolded Bottlenosed Dolphin. (Abs.) *Jour. Acoust. Soc. Am.* **64** (Suppl. 1): S87.

See Nachtigall et al., 1980, below.

Nachtigall, P. E., A. E. Murchison, and W. W. L. Au. 1980. Cylinder and Cube Shape Discrimination by an Echolocating Blindfolded Bottlenosed Dolphin. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 945-947.

The dolphin could discriminate the cylinder as its aspect was changed except when the flat top of the cylinder faced the animal. Acoustic examination of the targets failed to reveal consistent and obvious echo cues for the discrimination of shape, but replicated measurements of target strength for each target revealed differences in standard deviations that paralleled the performance of the animal.

Nachtigall, P. E. 1980. Odontocete Echolocation Performance on Object Size, Shape and Material. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 71-95.

A review.

Nachtigall, P. E. 1980. Bibliography of Echolocation Papers on Aquatic Mammals Published Between 1966 and 1978. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish, (eds.). Plenum Press, New York, pp. 1029-1069.

Lists 580 references, many from the Soviet literature.

Nachtigall, P. E. and S. A. Patterson. 1980. Echolocation Sameness-Difference Discrimination by the Atlantic Bottlenosed Dolphin (*Tursiops truncatus*) (Abs.) *Jour. Acoust Soc. Am.* **68** (Suppl. 1): S98.

A dolphin was trained to respond differently to two simultaneously presented stimulus objects, depending on whether they were identical or different. After development of the sameness-difference concept, novel stimuli were similarly presented, and following successful completion of this test, sensory modality transfer was also achieved when the animal was blindfolded with rubber eyecups.

Nachtigall, P. E. and P. W. B. Moore (eds.). 1988. Animal Sonar Processes and Performance. 862 pp. NATO ASI Series, Series A: *Life Sciences*. Vol. 156. Plenum Press, New York.

This volume presents the proceedings of a NATO Advanced Study Institute on Animal Sonar Systems held September 10-19, 1986 in Helsignor, Denmark. This was the third international meeting on biosonar and contributors presented their most recent works. Topics included: (1) Echolocation signals and their production, (2) Auditory systems of echolocating animals, (3) Performance of animal sonar systems, (4) Natural history of echolocation, (5) Echolocation and cognition, and (6) Echolocation theory and applications.

Nachtigall, P. E. 1989. Sounds of a Stranded Pygmy Sperm Whale (*Kogia breviceps*). (Abs.) European Association for Aquatic Mammals, Tenerife, Spain.

Description of recordings made of a pygmy sperm whale beached on the northeast shore of Oahu, Hawaii.

Nachtigall, P. E., W.W.L. Au, J.L. Pawloski, and P.W.B. Moore. 1995. Risso's Dolphin (*Grampus griseus*) Hearing Thresholds in Kaneohe Bay, Hawaii. In: *Sensory Systems of Aquatic Mammals*, R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds), De Spil, Woerden, Netherlands, pp. 49-53.

The first audiogram for the Risso's dolphin is reported. Conduct of the study in the natural environment of Kaneohe Bay, Oahu, Hawaii, limited determination of relative peak sensitivity. Data allow comparison with audiograms of other animals, indicating the Risso's dolphin apparently hears high frequencies like other odontocetes.

Nachtigall, P.E., W.W.L. Au, and J.L. Pawloski. 1995. Low Frequency Hearing of *Pseudorca crassidens* and *Grampus griseus*. (Abs.) 11th Biennial Conf. on the Biology of Marine Mammals, p. 82.

Reports on measurement studies of underwater behavioral hearing thresholds for a false killer whale (*Pseudorca crassidens*) and a Risso's dolphin (*Grampus griseus*). In contrast to previously demonstrated very sensitive hearing at higher frequencies, both animals showed very poor hearing at the lower frequencies.

Nachtigall, P.E., W.W.L. Au, and J. Pawloski. 1996. Low-Frequency Hearing in Three Species of Odontocetes. (Abs.). *Jour. Acoust. Soc. Am.* **100** (4, Pt. 2): 2611.

Low-frequency underwater hearing thresholds for pure-tone signals between 75 and 1600 Hz were determined for an Atlantic bottlenose dolphin, a false killer whale and a Risso's dolphin, using behavioral measures. The animals showed relatively poor hearing at these lower frequencies.

Norris, K. S. and E. C. Evans III. 1988. On the Evolution of Acoustic Communication Systems in Vertebrates, Part I: Historical Aspects. In: *Animal Sonar Processes and Performances*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 655-669.

The evolution of vertebrate communication and echolocation is described. Development of auditory structures are described by five general levels of structural advancement. A review of acoustic communication systems for major animal groups is presented. The emergence of echolocation is described. For a discussion of cognitive aspects see Evans and Norris, 1988.

Northrop, J., W. C. Cummings, and P. O. Thompson. 1968. 20-Hz Signals Observed in the Central Pacific. *Jour. Acoust. Soc. Am.* **43** (2):383-384.

20-Hz signals recorded in the mid-Pacific area had source levels that ranged from 65 to 100 dB re 1 ubar at 1 yard. The original strength, source movement, and seasonal peak suggested the sounds were from a biological source, probably the finback whale.

Northrop, J., W. C. Cummings, and M. F. Morrison. 1971. Underwater 20-Hz Signals Recorded Near Midway Island. *Jour. Acoust. Soc. Am*. **49** (6, Pt. 2): 1909-1910.

This paper describes doublets of 25-second, 20-Hz signals believed to be from whales. Signals occurred in trains of source levels ranging from 53 to 71 dB re 1 ubar at 1 yard.

Pawloski, D. A. and P. W. B. Moore. 1987. Combined Stimulus Control of Peak Frequency and Source Level in the Echolocating Dolphin (*Tursiops truncatus*). 15th Annual IMATA Conf., New Orleans, LA, Oct. 26, 1987, pp. 3-9.

The training methods by which an echolocating dolphin was trained to control its emitted source level and the frequency content of the echolocation click are presented.

Penner, R. H. and A. E. Murchison. 1970. Experimentally Demonstrated Echolocation in the Amazon River Porpoise, *Inia geoffrensis*. NUC TP 187, 28 pp.

An analysis of the ability of a freshwater porpoise to discriminate, by echolocation, wires or tubes of different diameters.

Penner, R. H. and J. Kadane. 1980. *Tursiops* Biosonar Detection in Noise. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 957-959.

In a detection problem in a high ambient noise environment with presentation of white noise at five different levels, the overall performance of two *Tursiops* degraded as noise level increased. The click count ("echolocation effort") and response latency both increased until the noise exceeded 77 dB. At the two highest levels, 82 and 87 dB, the click trains became shorter and latencies were longer.

Penner, R. H. and J. Kadane. 1980. Biosonar Interpulse Interval as an Indicator of Attending Distance in *Tursiops truncatus*. (Abs.) *Jour. Acoust. Soc. Am.* **80** (Suppl. 1): S97.

In a biosonar detection study, the relationship between interpulse interval lengths and calculated acoustical two-way travel time was found to describe an attending distance appropriate to the distance between animal and target.

Penner, R. H. and C. W. Turl. 1983. Bottlenosed dolphin (*Tursiops truncatus*): Difference in the pattern of interpulse intervals. (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S74.

When the echolocation detection abilities of a bottlenosed dolphin and a beluga were tested on identical targets at the same distances, their interpulse interval distributions differed, but detection accuracy was not significantly different.

Penner, R. H., C. W. Turl, and W. W. L. Au. 1986. Target Detection by the Beluga Using a Surface-Reflected Path. *Jour. Acoust. Soc. Am.* **80**:1842-1843.

During an echolocation-in-noise experiment, a beluga was suspected of using a surface-reflected path to maximize detection performance. Tests confirmed this.

Penner, R. H. 1988. Attention and Detection in Dolphin Echolocation. In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 707-713.

The results of experiments examining the interpulse interval of echolocation pulses in the bottlenosed dolphin are presented. The effect of target distance on interpulse interval is discussed.

Powell, B. A. 1966. Periodicity of Vocal Activity of Captive Atlantic Bottlenosed Dolphins (*Tursiops truncatus*). *Bull. So. Calif. Acad. Sci.* **65** (4): 237-244.

Periodicity of vocal activity was found to be related to feeding periods and could be altered by changing the feeding schedule.

Ridgway, S. H. 1980. Electrophysiological Experiments on Hearing in Odontocetes. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 484--493.

Review of findings on dolphin hearing, with accounts of modern anatomic and physiologic work on the ear; the brain, evoked potentials, and audition; and evidence that sound production can be used to assess dolphin health and mood.

Ridgway, S. H., D. A. Carder, R. F. Green, A. S. Gaunt, S. L.L. Gaunt, and W. E. Evans. 1980. Electromyographic and Pressure Events in the Nasolaryngeal System of Dolphins During Sound Production. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 239-249.

Study of the gross and microanatomical nature of the nasal plug nodes, diagonal membrane, and nasofrontal sacs, coupled with acoustic, electromyographic, and pressure measurements strongly indicated that this system constitutes the source of sound production. The data show no evidence for sound production in the larynx.

Ridgway, S. H. 1983. Dolphin Sound Production: Physiologic, Diurnal, and Behavioral Correlations. (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S73.

Identifies unanswered questions regarding mechanics of dolphin sound production and states findings on correlations identified in the title.

Ridgway, S. H. and D. A. Carder. 1983. Audiograms for Large Cetaceans: A Proposed Method for Field Studies. (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S53.

Audiograms for small cetaceans have been produced by the averaged-brainstem response technique using EEGs recorded when sound pulses are presented via a hydrophone. It is proposed that this technique could be used to obtain audiograms from large whales that have become trapped, stranded, or beached.

Ridgway, S. H. and D. A. Carder. 1988. Nasal Pressure and Sound Production in an Echolocating White Whale (*Delphinapterus leucas*). In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 53-60.

Nasal cavity pressures were measured while an echolocating beluga performed a discrimination task; the pressures increased whenever the whale emitted echolocation pulses or whistles. Open catheters distorted or prevented pulse and whistle production. The nasal apparatus is structured to tolerate high differential pressures produced during sound production; such pressure would be detrimental to critical thoracic circulation.

Ridgway, S. H. and D. A. Carder. 1990. Sounds Made by a Neonatal Sperm Whale, *Physter* spp. *Jour. Acoust. Soc. Am.* **88** (Suppl. 1): S6.

Broadband recordings were made from a baby sperm whale. The sounds of the whale were described according to type and location of production.

Ridgway, S. H., D.A. Carder, and T.A. Romano 1991. The Victory Squeal of Dolphins and White Whales at the Surface and at 100m or More in Depth. *Jour. Acoust. Soc. Am.* **90**:2335.

Investigates and analyzes the victory squeal, a recognizable rapid pulse train of dolphins and white whales after successfully completing auditory tasks.

Ridgway, S. H., D. A. Carder, P. L. Kamolnick, D. J. Skaar, and A. Root 1991. Acoustic Response Times (RTs) for *Tursiops truncatus*. *Jour. Acoust. Soc. Am.* **89**:1967-1968.

Dolphins (*Tursiops truncatus*) were trained to make underwater acoustic responses (ARs = whistles or pulse trains) to tonal or click train stimuli (St). St delivery and AR and RT recordings were computer controlled. Response times (RTs) varied with the individual bottlenosed dolphin, and with amplitude and duration of St. Median RT typically was less than the mean by one to five percent. Median simple RT (1 St, 1 AR) ranged from 145 msec to just over 300 msec. Median choice RT (2 unlike random St, 2 unlike ARs) ranged from 170 to 448 msec.

Ridgway, S.H. and D.A. Carder. 1993. High-Frequency Hearing Loss in Old (25+ Years Old) Male Dolphins. *Jour. Acoust. Soc. Am.* **94** (3): 1830.

Old male dolphins tend to have high frequency hearing loss not typically found in young males and females or in old females.

Ridgway, S.H. and D.A. Carder. 1994. Auditory Evoked Potentials for Assessment of Hearing in Marine Mammals. *Jour. Acoust. Soc. Am.* **96**: 3269.

The development of a method for collecting hearing data in non-trained animals including beached or entrapped large whales is described.

Ridgway, S.H. and D.A. Carder. 1995. Whale Physiology at Depth: Hearing, Sonar, and Homeostasis. 26th Annual Conf. of the International Association for Aquatic Animal Medicine. Mystic, CT, May 16-10, 1995, **26**: 67.

A preliminary film report describing methods and approaches for studying hearing and physiology of trained whales in the open ocean.

Ridgway, S.H. and D.A. Carder. 1995. Deep Hearing and Sonar Studies of Conditioned White Whales, *Delphinapterus leucas*. 11th Biennial Conf. on the Biology of Marine Mammals, Orlando, FL, Dec. 14-18, p. 96.

Hearing testing of white whales diving as deep as 200 m was described and a film report was presented.

Ridgway, S.H. and D.A. Carder. 1996. Hearing Deficits Measured in Some *Tursiops truncatus*, and Discovery of a Deaf/Mute Dolphin. 26th Annual Conf. of the International Association for Aquatic Animal Medicine, Mystic, CT, May 16-10, 1995, **26**: 41.

Eight dolphins were tested for hearing ability. Three males showed hearing disability at higher frequencies above about 60 kHz. An animal with behavioral indications of hearing deficit was tested and found to be deaf.

Ridgway, S.H. 1997. Who are the Whales? *Bioacoustics*. **8**: 3-20.

Cetaceans are born in water and spend their entire lives in the aquatic medium. Small and large species occupy all oceans from the equator to the polar seas; some inhabit rivers; and four species live only in fresh water. There is a great gap in knowledge about hearing in most cetacean species and especially about how noise and high-intensity sound may affect all cetaceans and other mammals under water. Studies of temporary threshold shift (TTS) and occupational noise exposure in human divers suggest a cautious approach to cetacean noise exposure until data on cetacean TTS can give some idea of the dynamic range of their ears.

Ridgway, S.H. 1997. Toward a Scientific Basis for Understanding Noise Effects on Marine Mammals. International Association for Aquatic Animal Medicine, Harderwijk, The Netherlands, May 3-8, p. 1-2.

This study determined the effect of depth on hearing of two white whales trained to dive down to 300 meters in the Pacific Ocean. Demonstrated capability for acoustic testing of whales in their natural environment, the open sea, and provided the first audiogram of any whale in the open sea.

Ridgway, S.H. and D.A. Carder. 1997. Hearing Deficits Measured in Some *Tursiops truncatus*, and Discovery of a Deaf/Mute Dolphin. *Jour. Acoust. Soc. Am.* **101** (1): 590-594.

See Ridgway and Carder, 1996, above.

Ridgway, S.H., D.A. Carder, R. Smith, T. Kamolnick, and W. Elsberry. 1997. First Audiogram for Marine Mammals in the Open Ocean and at Depth: Hearing and Whistling by Two White Whales Down to 30 Atmospheres. *Jour. Acoust. Soc. Am.* **101**: 3136.

To test the effect of depth on the hearing of an odontocete cetacean, two white whales were trained to dive and station on a platform at 5, 100, 200, or 300 m in the Pacific Ocean and whistle when they heard a 500 ms tone from a hydrophone. Findings after 885 dives support theories that sound is conducted through whale head tissues to the ear without the usual ear drum/ossicular chain amplification of the aerial middle ear. These first ever hearing tests in the open ocean demonstrate that whales hear as well at depth as near the surface; therefore, zones of influence for human-made sound are just as great throughout the depths to which whales dive, or at least to 300 m.

Roitblat, H. L., R. H. Penner, and P. E. Nachtigall. 1988. Delayed Matching-To-Sample by an Echolocating Bottlenosed Dolphin. (Abs.) *Jour. Acoust. Soc. Am.* **84** (Suppl. 1): S77.

A bottlenosed dolphin's clicks were monitored in a three-alternative, delayed matching-to-sample experiment. Analysis showed a complex decision-making process combining stereotypic and contingent behavior to produce accurate performance.

Roitblat, H. L., R. L. Penner, and P. E. Nachtigall. 1989. Echolocation Matching-to-Sample: The Microstructure of Decision-making. (Abs.) *Bulletin of the Psychonomic Society*. 30th Annual Mtg. of the Psychonomic Society, Atlanta, GA., **27**(6):495.

A bottlenosed dolphin was studied in a three-alternative matching-to-sample echolocation task. Distribution of effort during the task was related to stimulus characteristics to help define the dolphin's decision-making process.

Roitblat, H. L., R. H. Penner, and P. E. Nachtigall. 1990. Attention and Decision-Making in Echolocation Matching-to-Sample by a Bottlenosed Dolphin (*Tursiops truncatus*): The Microstructure of Decision-Making. In: *Sensory Abilities of Cetaceans*, J. Thomas and R. Kastelein (eds.). Plenum Press, New York, pp. 665-676.

A discussion of the sequential sampling model and the problems of combining information from successive echoes. This paper also describes how the dolphin's echo-location signal varied over successive clicks.

Roitblat, H. L., R. H. Penner, and P. E. Nachtigall. 1990. Matching-to-Sample by an Echolocating Dolphin. *Jour. Exper. Pysch: Animal Behavior Processes*. **16**(1):85-95.

Describes a dolphin's recognition performance and develops a sequential sampling model of dolphin choice performance in a delayed matching-to-sample task.

Roitblat, H. L., P. W. B. Moore, D. A. Helweg, and P. E. Nachtigall. 1991. Material Matching by a Bottlenosed Dolphin. (Abs.). *Bulletin of the Psychonomic Society*. 32nd Annual Mtg. of the Psychonomic Society, San Francisco, November 1991, **29**(6):504.

Describes preliminary data concerning the dolphin’s ability to discriminate stimuli that varied only in internal material, but were identical in shape.

Roitblat, H. L., L. M. Herman, and P. E. Nachtigall. 1993. *Language and Communication: Comparative Perspectives*. Lawrence Erlbaum Associates, Hillsdale, NJ, 502 pp.

This book was the product of a conference on language and related cognitive processes in animals, which brought together scientists working on language and communication, to review the work done on language in apes and dolphins, and to place this work in a larger perspective of animal communication and cognition.

Roitblat, H.L., D.A. Helweg and H.E. Harley. 1995. Echolocation and Imagery. In: *Sensory Systems of Aquatic Mammals*, R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (eds.), DeSpil Publishers, Woerden, The Netherlands, pp. 171-181.

Discusses the concept of imagery—
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Schusterman, R. J. and P. W. B. Moore. 1978. Underwater Audiogram of the Northern Fur Seal (*Callorhinus ursinus*) *Jour. Acoust. Soc. Am.* **64** (Suppl. 1A): S87.

The underwater audiogram of two Alaskan fur seals is presented.

Schusterman, R. J. 1980. Behavioral Methodology in Echolocation by Marine Mammals. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 11-41.

A comprehensive review of methodology and experimental design in echolocation studies of marine mammals.

Schusterman, R. J., D. A. Kersting, and W. W. L. Au. 1980. Response Bias and Attention in Discriminative Echolocation by *Tursiops truncatus*. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 983-986.

Describes an experiment testing the notion that a response bias acquired in an unsolvable discriminative echolocation task will strongly influence the attention of a dolphin in a similar but solvable task. The results indicated this occurred.

Schusterman, R. J. and P. W. B. Moore. 1980. Auditory Sensitivity of Northern Fur Seals (*Callorhinus ursinus*) and a California Sea Lion (*Zalophus californianus*) to Airborne Sound. (Abs.). *Jour. Acoust. Soc. Am.* **68** (Suppl. 1): S6.

At even frequencies, from 1 to 30 kHz, the thresholds, although inferior in air compared to water, showed good accommodation for hearing airborne sounds. The otariic pinnipeds appear to be more sensitive to airborne sounds than do the phocid pininipeds.

Schusterman, R. J., D. A. Kersting, and W. W. L. Au. 1980. Stimulus Control of Echolocation Pulses in *Tursiops truncatus*. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 981-982.

A major problem in determining what cue or set of cues a dolphin uses in target detection or discrimination has been the ambiguous nature of the echo return relative to the position of the dolphin. In this experiment the problem was solved by training the dolphin to position precisely and emit echolocation pulses on cue.

Schusterman, R. J. and P. W. B. Moore. 1981. Noise Disturbance and Audibility in Pinnipeds. *Jour. Acoust. Soc. Am.* **70** (Suppl. 1A): S83.

Noise and its disturbance impact on various species of wild pinnipeds are discussed.

Scronce, B. L. and C. S. Johnson. 1975. Bistatic Target Detection by a Bottlenosed Porpoise. *Jour. Acoust. Soc. Am.* **59**(4):1001-1002.

The porpoise was acoustically masked to prevent use of its echolocation pulses and trained to report the presence or absence of a 7.62-cm-diameter hollow stainless steel sphere by listening. The sphere was ensonified by a broadband, click-type pulse.

Scronce, B. L. and S. H. Ridgway. 1980. Gray seal, *Halichoerus*: Echolocation Not Demonstrated. In: *Animal Sonar Systems*, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 991-993.

A gray seal, trained to wear a blindfold, was tested for echolocation capability in detection and discrimination tasks. Successful detection of an air-filled ring occurred with and without head scanning and emission of click trains, suggesting that the ring was a good passive target. Performance in a discrimination task was at a chance level.

Scronce, B. L. and S. H. Ridgway. 1983. Seal Blindfolded Discrimination: Echolocation Not Proven in *Halichoerus grypus*. (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S75.

Experiments with a gray seal trained to wear an opaque band that blocked vision provided no evidence of an echolocation capability.

Seeley, R. L., W. F. Flanigan, Jr., and S. H. Ridgway. 1976. A Technique for Rapidly Assessing the Hearing of the Bottlenosed Porpoise (*Tursiops truncatus*). NUC TP 522, 15pp.

Brainwave activity was used to determine approximate auditory “threshold” levels. This rapid (4-6 hour) technique provides an estimation of the hearing ability of an unanesthetized porpoise over a frequency range of 5 to 200 kHz and could be used to screen hearing in other marine mammals.

Sigurdson, J. E. 1987. Reproduction of Frequency-Modulated Tones by Dolphins (*Tursiops truncatus*) (Abs.). Seventh Biennial Conf. on the Biology of Marine Mammals, Society of Marine Mammalogy, Miami, FL., p. 64.

The ability of a bottlenosed dolphin to reproduce artificial, frequency-modulated whistles was evaluated. The animal was trained to produce highly accurate reproductions of each of three acoustic models in separate training sequences. The results demonstrate the flexibility of the animal’s sound-producing mechanism as well as the feasibility of preprogrammed training and evaluation of acoustic responses.

Sigurdson, J. E. 1989. Frequency-Modulated Whistles as a Medium for Communication with the Bottlenose Dolphin (*Tursiops truncatus*). (Abs.) Animal Language Workshop, Honolulu, HI, April 1989.

Review of procedures and early findings on the use of operant contingencies to condition FM CW whistles.

Sigurdson, J. E. 1991. Echolocation Pulse-Rate and Head-Azimuth of an Atlantic Bottlenose Dolphin in a Detection Task. (Abs.) *Jour. Acoust. Soc. Am.* **90** (4, Pt. 2): 2334.

Report of procedures and initial findings for biosonar search and detection of water-column objects in an open field. Baseline performance descriptions as well as pulse-count and echo-pulse interval as functions of object distance.

Sigurdson, J. E. 1991. Reproduction of Arbitrary Frequency-Modulated Tones and Object Labeling by Dolphins (*Tursiops truncatus*). (Abs.) Ninth Biennial Conf. on the Biology of Marine Mammals, Chicago, IL, Dec. 1991.

Reports the successful four-alternative, conditional discrimination of four objects using four conditioned, arbitrary, FM CW acoustic responses that were evaluated in real-time with automated signal recognition.

Sigurdson, J. E. 1993. Frequency-Modulated Whistles as a Medium for Communication with the Bottlenose Dolphin (*Tursiops truncatus*). In: *Language and Communication: Comparative Perspectives*, H.L. Roitblat, L.M. Herman and P.E. Nachtigall (eds.). Lawrence Erlbaum Associates, Erlbaum, NJ, pp. 153-173.

Research review with current methods and results of conditioning FM CW signals with operant contingencies to match arbitrary acoustic models. Controlled training and testing demonstrate that operant contingencies alone are not sufficient to induce model-copying behavior or "acoustic mimicry." Probable causes are discussed.

Sigurdson, J. E. 1994. Dynamics of Biosonar Echolocation in the Dolphin. (Abs.) Critical Issues in Replicating Biosonar Conference, San Diego, CA, Dec. 1994.

Reviewed work on biosonar dynamics with proposals for future research.

Sigurdson, J. E. 1994. Dynamics of Dolphin Biosonar Search and Detection. (Abs.) *Jour. Acoust. Soc. Am.* **96** (5, Pt. 2): 3316.

Results of 2-D search and detection of water-column objects in an open field from an enclosed pen. Extensions for open-ocean research were described.

Sigurdson, J. E. 1996. Open-Water Echolocation of Bottom Objects by Dolphins (*Tursiops truncatus*). (Abs.) *Jour. Acoust. Soc. Am.* **100** (4, Pt. 2): 2610.

The attitude, azimuth, pulse-rate and waveform were recorded during open-water search for bottom objects. Results include baseline dynamic performance, search-pattern adaptation to experience, head attitude/azimuth and pulse-rate correlations with object location and inverse variation of pulse-count with object-distance. Spectral modulation as a function of background and novelty was analyzed.

Sigurdson, J. E. 1997. Adaptations of Dolphin Biosonar to the SW/VSW Environment. (Abs.) Abstracts of the Environmentally Adaptive Sonar Technology (EAST) Symposium. Seattle, WA, Jan. 1997.

Described the major physiological adaptations of dolphin biosonar to shallow and very shallow water and the effects of experience on the dynamic use of that sonar in open-water search and detection tasks.

Sigurdson, J. E. 1997. Analyzing the Dynamics of Dolphin Biosonar During Search and Detection Tasks. Invited paper. Symposium on Underwater Bio-Sonar and Bioacoustics, British Institute of Acoustics, Loughborough University, Vol. 19, No. 9, pp. 123-132.

Describes technology for measurement of head movements and acoustic output of the bottlenose dolphin as well as methods for testing and analysis of the animal's dynamic biosonar performance. Data presented on biosonar performance during search for and detection of water-column objects in an open field and bottom objects in the open ocean.

Sigurdson, J. E. 1997. Biosonar Dynamics of the Bottlenose Dolphin in VSW Search and Detection Tasks. (Abs.) *Jour. Acoust. Soc. Am.* **105** (5, Pt. 2): 3133.

Describes initial analysis of the dolphin's dynamic biosonar performance during search for and detection of bottom objects in the open ocean. Findings included quantitative descriptions of typical 3-D search patterns, shorter than expected echo-pulse intervals and spectral variation between pulses that appeared to correlate with grazing angle and distance.

Thomas, J.A. 1987. Factors That May Affect Sound Propagation from Acoustic Harassment Devices. Proceedings, Acoustical Deterrents in Marine Mammal Conflicts with Fisheries Workshop, B.R. Mate and J.T. Harvey (eds.) Newport, OR, Febr. 17-18, 1986. Oregon State University Publication No. ORESUW-86-001.

The oceanographic conditions that could affect the use of acoustic devices to control movements of marine mammals around fishing grounds are described. Some species of specific concerns are given. In addition, some practical and logistical considerations are described relative to the use of sounds to deter marine mammals around human activities.

Thomas, J. A., R. A. Puddicombe, M. George, and D. Lewis. 1988. Variations in Underwater Vocalizations of Weddell Seals (*Leptonychotes weddelli*) at the Vestfold Hills as a Measure of Breeding Population Discreetness. *Hydrobiologia* **165**:279-284.

Common characteristics of vocalizations were compared to assess the degree of mixing among populations from three areas. Results indicate one population was distinct.

Thomas, J. A., M. Stoermer, C. Bowers, L. Anderson, and A. Garver. 1988. Detection Abilities and Signal Characteristics of Echolocating False Killer Whales (*Pseudorca crassidens*). In: *Animal Sonar Processes and Performance*, P. E. Nachtigall and P. W. B. Moore (eds.). Plenum Press, New York, pp. 323-328.

Preliminary studies of echolocation abilities were conducted on false killer whales housed at Sea World San Diego and Sea Life Park in Hawaii. This study showed this species could detect a metal sphere at short ranges when not visible by using echolocation. Some low-frequency and high-frequency components were present in the echolocation clicks.

Thomas, J. A., N. K. W. Chun, W. W. L. Au, and K. Pugh. 1988. Underwater Audiogram of a False Killer Whale (*Pseudorca crassidens*). *Jour. Acoust. Soc. Am.* **84** (3): 936-940.

The behavioral audiogram showed maximum sensitivities between 16 and 64 kHz and was similar to beluga whale and bottlenosed dolphin sensitivities. Sensitivity decreased rapidly above 64 kHz.

Thomas, J. A., W. W. L. Au, C. W. Turl, and J. L. Pawloski. 1989. Sensory Systems of False Killer Whales. (Abs.) Eighth Biennial Conf. on the Biology of Marine Mammals, Society of Marine Mammalogy, Pacific Grove, CA., p. 67.

Studies on hearing and echolocation abilities are summarized. Results compared with bottlenosed dolphin and beluga studies.

Thomas, J. A. and C. W. Turl. 1990. Echolocation Characteristics and Range Detection Threshold of a False Killer Whale (*Pseudorca crassidens*). In: *Sensory Abilities of Cetaceans*, J. A. Thomas and R.A. Kastelein (eds.). Plenum Press, New York, pp. 321-334.

The range-detection abilities for a false killer whale was tested on Skyhook II range in Kaneohe Bay, Hawaii. The target was a 7.6-cm-diameter hollow metal sphere. The maximum detection range (50-percent correct detections) was measured at 115 meters. These values are comparable to belugas and bottlenosed dolphins tested on the same range.

Thomas, J. A., J. L. Pawloski, and W. W. L. Au. 1990. Masked Hearing Abilities in a False Killer Whale (*Pseudorca crassidens*). In: *Sensory Abilities of Cetaceans*, J. A. Thomas and R. A. Kastelein (eds.). Plenum Press, New York, pp. 395-404.

A masked hearing study was conducted on a female false killer whale using white noise as a masker. The response paradigm was a go/no-go and the signal was presented in staircase method. Three noise levels were used.

Thomas, J.A., P.W.B. Moore, P.E. Nachtigall, and W.G. Gilmartin. 1990. A New Sound From a Stranded Pygmy Sperm Whale. *Aquatic Mammals*. **16** (1): 28-30.

A pygmy sperm whale beached on the northeast shore of Oahu, Hawaii and was held temporarily at Sea Life Park. Underwater recordings were made using broadband equipment. On several occasions the animal produced a low-frequency, low-amplitude sound, but no echolocation-like clicks.

Thomas, J. A., P. W. B. Moore, R. Withrow, and M. Stoermer. 1990. Underwater Audiogram of a Hawaiian Monk Seal (*Monachus schauinslandi*). *Jour. Acoust. Soc. Am.* **87** (1): 417-420.

An underwater hearing test was conducted on a young male Hawaiian monk seal at Sea Life Park, Oahu, Hawaii. The response paradigm was go/no-go and signals were presented from 2 to 48 kHz using a staircase presentation. Maximum hearing sensitivity (20 dB from maximum sensitivity) was between 12 and 28 kHz.

Thompson, P. O. 1965. Deep-Water Recordings of Pinniped Sounds. Addendum to Proceedings, Second Conf. on Biological Sonar and Diving Mammals, Menlo Park, CA, 11pp.

Describes, in detail, underwater recordings of barking sounds from California sea lions off San Clemente Island. Diurnal characteristics, spectrum plots, and sonograms are included.

Thompson, P. O. and W. C. Cummings. 1969. Sound Production of the Finback Whale (*Balaenoptera physalus*) and Eden's whale (*B. edeni*) in the Gulf of California. (Abs.) Sixth Conf. on Biological Sonar and Diving Mammals, Menlo Park, CA, p. 109.

Describes powerful, low-frequency sounds from two species of whales found in the Gulf of California. Finback signals ranged from 20 to 100 Hz, while those from Eden's whales averaged 124 Hz. Although finbacks have been suspected as sources of 20-Hz signals, these were not encountered among the 1800 phonations recorded from some 70 finbacks.

Thompson, P. O. 1978. Underwater Repetitive Mammal Sound Sequences in the Bering Strait. (Abs.) *Jour. Acoust. Soc. Am.* **64** (Suppl. 1): S87.

Sounds similar to, but simpler than, the "songs" of the humpback whales were recorded. Among possible sources were the walrus and the bowhead whale.

Thompson, P. O. and W. A. Friedl. 1982. A Long-Term Study of Low-Frequency Sounds from Several Species of Whales off Oahu, Hawaii. *Cetology*, No. **45**, 19 pp.

Two bottom-mounted hydrophones were monitored from December 1978 through April 1981. Sounds of five whale species (humpback, fin, blue, sperm, and pilot) were identified. The “boing” sound was also recorded. Sounds were received most frequently in winter and spring, least frequently in July and October.

Turl, C. W. and R. H. Penner. 1983. Target Detection: Beluga Whale and Bottlenosed Dolphin Echolocation Abilities Compared. (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S74.

No significant difference in performance was found for five targets of the same size and target strength at distances of 40 to 120 m.

Turl, C. W. 1987. The Ability of the California Sea Lion (*Zalophus californianus*) to Bistatically Detect and Localize Echoes from Underwater Targets. *Jour. Acoust. Soc. Am.* **82**(1):381-383.

A sea lion was required to detect and orient to echoes in noise. The sea lion’s performance decreased as S/N ratio decreased.

Turl, C. W., R. H. Penner, and W. W. L. Au. 1987. Comparison of Target Detection Capabilities of the Beluga and Bottlenosed Dolphin. *Jour. Acoust. Soc. Am.* **82** (5): 1487-1491.

The echolocation capabilities of a beluga (*Delphinapterus leucas*) and an Atlantic bottlenosed dolphin (*Tursiops truncatus*) were directly compared in a target detection experiment. Both animals were trained to detect targets in the presence of masking noise. Target detection performance was determined as a function of masking noise level at each target distance. The echo-to-noise ratio for the beluga at the 75-percent correct response threshold was approximately 1.0 dB compared to about 10 dB for the dolphin.

Turl, C. W., R. H. Penner, and W. W. L. Au. 1988. Masked Detection Thresholds for the Beluga and Bottlenosed Dolphin. In: *Port and Ocean Engineering Under Arctic Conditions*, Vol. II, W. M. Sackinger, M. O. Jeffries, J. L. Imm and S. D. Treacy (eds.). Symposium on Noise and Marine Mammals. Geophysical Institute, University of Alaska, pp. 89-93.

A beluga and a bottlenosed dolphin detected spherical targets in noise at three distances. The beluga’s echo-to-noise ratio was approximately 10 dB better than the dolphin’s for all target ranges.

Turl, C. W. and R. H. Penner. 1989. Differences in Echolocation Click Patterns of the Beluga (*Delphinapterus leucas*) and the Bottlenosed Dolphin (*Tursiops truncatus*). *Jour. Acoust. Soc. Am.* **86** (2):497-502.

In an echolocation experiment, the target detection of a beluga and a bottlenosed dolphin were similar, but each produced different patterns of echolocation click trains. The beluga emitted click trains that were composed of “packets of clicks.” The interpacket interval is longer than the total packet duration and greater than the two-way travel time from the animal to the target. This suggests that the beluga can process all echoes of a packet before the next packet returns to the animal. The bottlenosed dolphin always emitted single clicks that are greater than the two-way travel time to the target.

Turl, C. W. 1991. Echolocation Abilities of the Beluga (*Delphinapterus leucas*): A Review and Comparison with the Bottlenosed Dolphin (*Tursiops truncatus*). In: *Advances in Research on the Beluga Whales (Delphinapterus leucas)*, T. G. Smith, D. J. St. Aubin, and J. R. Geraci (eds.). *Canadian Bulletin of Fisheries and Aquatic Sciences* **224**:119-128.

A review. The beluga's bioacoustic abilities are not fully known, but information suggests its echolocation system is particularly well-suited to function in the Arctic environment.

Turl, C. W., D. J. Skaar, and W. W. L. Au. 1991. The Echolocation Ability of the Beluga (*Delphinapterus leucas*) to Detect Targets in Clutter. *Jour. Acoust. Soc. Am.* **89** (2): 896-901.

A beluga was trained to detect different length cylinders in front of a clutter screen at five separation distances. Detection data were collected on the beluga's performance as function of the separation between the targets and clutter screen. The beluga's performance was above 80 percent correct detection for the 14- and 10-cm cylinders as the separation distance decreased from 10.1 to 5.1 cm. For all targets except the 3-cm cylinder, the beluga's performance was higher at 0-cm separation than at 2. 5-cm separation. The results indicate that a beluga can detect targets in 3.6 to 5.4 dB more reverberation than previously reported for a bottlenosed dolphin.

Turl, C.W. and J.A. Thomas. 1992. Possible Relationship Between Oceanographic Conditions and Long Range Target Detection by a False Killer Whale. In: *Marine Mammal Sensory Systems*, J.A. Thomas, R.A. Kastelein and A.Y. Supin (eds.). Plenum Press, New York.

Reports on study to determine whether sound velocity profiles in water of an echolocating false killer whale (*Pseudorca crassidens*) changes detection range. The whale's detection performance decreased as distance to the target increased.

Wenz, G. M. 1964. Curious Noises and the Sonic Environment in the Ocean. In: *Marine Bio-Acoustics*, Vol. 1, W. N. Tavolga (ed.). Pergamon Press, Elmsford, NY, pp. 101-119.

Describes ambient noise of the ocean—waves, precipitation, earthquakes, ships, marine organisms, etc., and discusses certain noises of biological origin, including some whose sources had not been identified.

Wever, E. G., J. G. McCormick, J. Palin, and S. H. Ridgway. 1972. Cochlear Structure in the Dolphin (*Langenorhynchus obliquidens*). *Proc. Nat. Acad. Sci. USA* **69** (3): 657-661.

Describes the microscopic structure of the cochlea and discusses the significance of cell numbers in the hearing of Langenorhynchus.

Wood, F. G. and W. E. Evans. 1980. Adaptiveness and Ecology of Echolocation in Toothed Whales. In: Animal Sonar Systems, R. G. Busnel and J. F. Fish (eds.). Plenum Press, New York, pp. 381-425.

Review of echolocation signal characteristics of various toothed whales with respect to their different ecological niches, foods, behaviors, etc. It is proposed that certain asymmetrical

features (skull, narial system) are related to the development of a sonar system. Differences in relative brain size appear to correspond to degree of adaptability, sensory integration, and versatility of sonar system.

2. NEURAL NETWORKS

Anderson, L.N., A.R. Rasmussen, W.W.L. Au., P.E. Nachtigall, and H.L. Roitblat. 1994. Neural Network Modeling of a Dolphin's Sonar Discrimination Capabilities. (Abs.). *Jour. Acoust. Soc. Am.* **96** (5, Pt. 2): 3316.

A previous modeling experiment used only spectral information of a dolphin's echo. In this study, both time and frequency information were used to model the dolphin discrimination capabilities.

Au, W.W.L. 1994. Comparison of Sonar Discrimination: Dolphin and an Artificial Neural Network. *Jour. Acoust. Soc. Am.* **95** (5, Pt. 1): 2728-2735.

Discusses comparison of capabilities of a dolphin and an artificial neural network to determine wall thicknesses of cylinders. The network was used to examine broadband echo features from the same cylinders employed in a earlier study of dolphin capabilities. Results indicate use of neural network technology may assist in understanding dolphin sonar and provide insights on different cues available for target discrimination.

Au, W.W.L. and P.E. Nachtigall. 1994. Artificial Neural Network Modeling of Dolphin Echolocation. (Abs.) Harderwijk Marine Mammal Sensory Symposium, Harderwijk, The Netherlands, April 28-May 3.

Discusses general concepts of artificial neural network modeling, with its application to dolphin echolocation in target discrimination tasks. Emphasizes a study comparing performance of a counterpropagation neural network and a dolphin in discriminating wall thickness differences of aluminum cylinders.

Au, W.W.L. and P.E. Nachtigall. 1995. Artificial Neural Network Modeling of Dolphin Echolocation. In: *Sensory Systems of Aquatic Mammals,* R. A. Kastelein, J.A. Thomas, and P.E. Nachtigall (eds.). DeSpil Publishers, Woerden, The Netherlands, pp. 183-199.

See Au and Nachtigall, 1994, above.

Au, W.W.L., L. Anderson, A. Rasmussen, H.L. Roitblat, and P.E. Nachtigall. 1995. Neural Network Modeling of a Dolphin's Sonar Discrimination Capabilities. *Jour. Acoust. Soc. Amer.* **98**: 43-50.

A counterpropagation neural network, a backpropagation neural network and a model using Euclidean distance measures were used to analyze digitized echoes from cylinders in an effort to model dolphin sonar discrimination capabilities. Both time and frequency information were used in the study. The backpropagation network outperformed the others, using spectral-only features of the echoes and also combined time and frequency features. In some specific instances, the backpropagation network also performed better than the dolphin.

Au, W.W.L., R.H. Shizumura, P.E. Nachtigall, R.J. Hicks, H.L. Roitblat, and G. Moons. 1996. Aspect-Independent Sonar Recognition of Cylinders Using Dolphin-Like Signals. (Abs.). *Jour. Acoust. Soc. Am.* **100** (4, Pt. 2): 2643.

Echoes of a dolphin-like sonar signal from four different cylinders were collected and used in a neural network recognition study. The network achieved better than 90 percent recognition of the echoes.

Helweg, D.A., H.L. Roitblat, and P.E. Nachtigall. 1993. Using a Neural Network to Model Dolphin Echolocation. In: *Artificial Neural Networks and Expert Systems*, N. Kasabov (ed.). IEEE Computer Society Press, Los Alamitos, CA, pp. 247-251.

A biomimetic neural network was used to model a bottlenose dolphin's ability to recognize aspect-dependent targets. Researchers used echo trains recorded during the dolphin trials to train an Integrator Gateway Network (IGN) to discriminate among the targets using echo spectra. The dolphin and the IGN learned to recognize geometric targets, even though orientation could vary. Results support the notion that ensonified underwater objects with complex shapes and echoes may be reliably classified using neural network architectures that are motivated through understanding of dolphin echolocation signals and performance.

Helweg, D.A. and P.W.B. Moore. 1997. Classification of Aspect-Dependent Targets by a Biomimetic Neural Network. NRaD TR 1747. 6 pp.

A biomimetic neural network was used to model a bottlenose dolphin's ability to recognize aspect-dependent targets. The results support the notion that ensonified mines with complex shapes and echoes may be reliably classified using neural network architectures motivated through understanding of marine mammal system echolocation signals and performance.

Moore, P. W. B., H. L. Roitblat, P. E. Nachtigall, and R. H. Penner. 1990. Classifying Dolphin Echoes Using an Integrator Gateway Artificial Neural Network. *Jour. Acoust. Soc. Am.* **90** (2): 2334.

See other articles by Moore, et al., 1990, below.

Moore, P. W. B., H. L. Roitblat, R. H. Penner, and P. E. Nachtigall. 1990. An Integrator Gateway Network for Recognizing Dolphin Echoes. Government Neural Network Applications Workshop, August 29-31, 1990, San Diego CA.

The application of the gateway integrator neural network for classifying various signals was presented in this classified workshop.

Moore, P. W. B., H. L. Roitblat, R. H. Penner, and P. E. Nachtigall. 1990. An Integrator Gateway Network for Recognizing Dolphin Echoes. Conf. on Neural Networks for Decision, Estimation, and Control, West Greenwich, RI.

A new neural network design based on the properties of the echolocating dolphin was presented and discussed in a classified conference on government signal-processing approaches.

Moore, P. W. B., H. L. Roitblat, P. E. Nachtigall, R. H. Penner, and W. W. L. Au. 1990. Sonar Target Recognition by an Artificial Neural Network. Naval Research and Development Information Exchange Conf., Naval Air Development Center, Warminster, PA, p. 48.

Detailed presentation of the integrator gateway network. This network (patent applied for) combines information from multiple signals and resets between trains of signals. This artificial neural network model was compared against a standard neural network model that did not include the integrating components and was found to improve object recognition substantially.

Roitblat, H. L., P. W. B. Moore, R. H. Penner, and P. E. Nachtigall. 1989. Clicks, Echoes, and Decisions: The Use of Information by a Bottlenosed Dolphin (*Tursiops truncatus*). (Abs.) Eighth Biennial Conf. on the Biology of Marine Mammals, Society of Marine Mammalogy, Pacific Grove, CA., p. 56.

Describes the pattern by which the dolphin searched alternative comparison stimuli in a delayed matching-to-sample task and some preliminary neural network models for dolphin echolocation.

Roitblat, H.L., P. W. B. Moore, P. E. Nachtigall, R. H. Penner, and W. W. L. Au. 1989. Natural Echolocation With an Artificial Neural Network. *International Journal of Neural Networks: Research and Applications* **1** (4): 239-248.

The performance of a dolphin performing in a matching-to-sample echolocation task was simulated with a counterpropagation artificial neural network. The neural network performance compared well with that of the dolphin when echoes collected while the dolphin echolocated were used.

Roitblat, H. L., P. W. B. Moore, P. E. Nachtigall, R. H. Penner, and W. W. L. Au. 1989. Dolphin Echolocation: Identification of Returning Echoes Using a Counterpropagation Network. International Joint Conf. on Neural Networks, Vol. 1, IEEE and International Neural Network Society, Piscataway, NJ, pp. 295-301.

Describes preliminary work on using a counterpropagation artificial neural network to recognize echoes from objects ensonified in a test pool by an artificial dolphin click and in Kaneohe Bay by a dolphin during performance of a delayed matching-to-sample task. Selected echoes were analyzed and successfully recognized by the network. Target recognition abilities of an echolocating dolphin and the neural network were also compared. In a noisy natural environment, the dolphin was 94.5 percent correct and the network was 96.7 percent correct. Possible applications of neural networks to echolocation studies are discussed.

Roitblat, H. L., P. W. B. Moore, P. E. Nachtigall, and R. H. Penner. 1991. Natural Dolphin Echo Recognition Using an Integrator Gateway Network. In: *Advances in Neural Information Processing Systems*, Vol. 3. D. S. Touretsky, J. E. Moody and R. Lippman (eds.). Morgan Kaufmann, San Mateo, CA, pp. 273-281.

Discusses the integrator gateway network for recognizing objects ensonified by dolphin echolocation signals.

Roitblat, H. L., P. W. B. Moore, P. E. Nachtigall, and R. H. Penner. 1991. Biomimetic Sonar Processing: From Dolphin Echolocation to Artificial Neural Networks. In: *From Animals to Animats*, J. A. Meyer and S. Wilson (eds.). MIT Press, Cambridge, MA, pp. 66-76.

Describes a dolphin's recognition performance and some aspects of a neural network model of echo recognition that incorporated properties of the sequential sampling model to combine information from successive dolphin echoes.

Root, W. A. and S. H. Ridgway. 1991. Neural Network Applications in Dolphin Response-time Studies. *Jour. Acoust. Soc. Am.* **90**: 2334.

Dolphins (*Tursiops truncatus*) were trained to make different sounds in response to two different acoustic stimuli produced by a computer system. A neural network was shown to be better at identifying response type and setting response latency than was a previously employed discriminant analysis routine.

3. PHYSIOLOGY/ANATOMY/GROWTH AND AGING

Adams, M. A. and P. E. Nachtigall. 1989. Chemical Communication in Dolphins: Chemical Constituents of the Perianal Gland (Abs.). 11th Annual Mtg., Assn. for Chemo-reception Sciences (AChemS XI), Sarasota, FL. *Chem. Senses* **14** (5): 681.

Samples of perianal gland secretions were collected from male *Tursiops*. Combined gas chromatography-mass spectrometry analysis identified several long-chain organic acids in the samples. The possibility of chemically mediated behavior in dolphins is discussed.

Bello, M. A., R. R. Roy, T. P. Martin, H. W. Goforth, Jr., and V. R. Edgerton. 1985. Axial Musculature in the Dolphin (*Tursiops truncatus*): Some Architectural and Histo-chemical Characteristics. *Marine Mammal Science* **1**: 324-336.

In view of reports that dolphins can swim faster than would be predicted based on physical features and presumed muscle power, this study examined muscle fiber types, fiber sizes and tendon arrangements of the dorsal and ventral axial muscles.

Briggs, M., W. Van Bonn, R. Linnehan, C. Messinger and S. Ridgway. 1995. Effects of Leuprolide Acetate in Depot Suspension on Testosterone Levels, Testicular Size and Semen Production in Male Atlantic Bottlenose Dolphins, *Tursiops truncatus*. 26th Annual Conf. of the International Association for Aquatic Animal Medicine, Mystic, CT, May 16-10, 1995, **26**:112.

Leuprolide acetate (Leupron) was shown to be effective at reducing testosterone levels, testes size and sperm production in male bottlenose dolphins. Results of this study indicate Leupron may be a suitable method of chemical contraception in adult male dolphins.

Briggs, M.B., D. Messinger, C. Messinger, R.M. Linnehan, W. Van Bonn, S.H. Ridgway and W.G Miller. 1996. Effects of Leuprolide Acetate in Depot Suspension on Testosterone Levels, Testicular Size and Semen Production in Male Atlantic Bottlenose Dolphins (*Tursiops truncatus*). American Association of Zoo Veterinarians Conf., Puerto Vallarta, Mexico, Nov. 1996, pp. 330-331.

Paper describes the results of a study of GnRH analog use in dolphins.

Brown, W. R., J. R. Geraci, B. D. Hicks, D. J. St. Aubin, and J. P. Schroeder. 1983. Epidermal Cell Proliferation in the Bottlenosed Dolphin (*Tursiops truncatus*). *Canadian Jour. Zool.* **61**: 1587-1590.

Using a radioactive labeling technique, the authors found that *Tursiops* has a large proliferative capacity which contributes to the unusual thickness of the skin.

Carder, D.A. and S.H. Ridgway. 1994. A Portable System for Physiological Assessment of Hearing in Marine Animals. *Jour. Acoust. Soc. Am.* **96** (5, Pt. 2): 3316.

Description of portable, stand-alone computer system for generating, digitizing and analyzing signals in the field.

Cartee, R.E., K. Broesmer and S.H. Ridgway. 1995. The Eye of the Bottlenose Dolphin (*Tursiops truncatus*) Evaluated by B-Mode Ultrasonography. *Jour. Zoo. and Wildlife Medicine*. **26** (3): 414-421.

The B-mode ultrasonographic images of bottlenose dolphin (*Tursiops truncatus*) eyes from cadavers and live animals were measured and compared with physical measurements of cadaver eyes. In live dolphins, eye diameters measured sonographically were not significantly different (2.55 cm x 2.32 cm) than either ultrasound or physical measurements. The optical axis diameter was 1.80 cm, and the circumference was 7.30 cm in live dolphins. Comparisons of circumference showed no significant difference between cadaver and live dolphin eye measurements.

Ceruti, M. G. 1983. Chemical Characteristics of Compounds Released by Marine Mammals. NOSC TR 930, 52 pp.

Excretions, secretions, and glandular extracts were analyzed to determine chemical constituents which may be involved in marine mammal chemoreception.

Ceruti, M. G., P. W. B. Moore, and S. A. Patterson. 1983. Peak Sound Pressure Level and Spectral Frequency Distributions in Echolocation Pulses of Atlantic Bottlenosed Dolphins (*Tursiops truncatus*). (Abs.) *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): S73.

Peaks in the average bimodal pulse spectrum occurred at 60 and 135 kHz or beyond, while the average unimodal pulse spectrum peaked at 120 kHz. Abstract includes other findings.

Ceruti, M. G., P. V. Fennessey, and S. S. Tjoa. 1985. Chemoreceptively Active Compounds in Secretions, Excretions, and Tissue Extracts of Marine Mammals. *Comp. Biochem. Physiol.* **32A**:505-514.

Hypothesizing that chemical communication may occur in marine mammals and that analysis of secretions and excretions would identify some specific compounds that might be involved, the authors determined the principal chemical components of sexual secretions, urine, feces, and blood from Atlantic *Tursiops*. Twenty-two identified compounds in aqueous solutions of sufficient concentration could be detected gustatorily by humans.

Colbert, A.A. 1996. Morphological Investigation of Variability in Bottlenose Dolphin (*Tursiops truncatus*) Skin for Use in Cutaneous Absorption Studies. Thesis, North Carolina State University, 92 pp.

Evaluates the morphological characteristics of *Tursiops truncatus* skin likely to impact dermal absorption kinetics to aid in the development of cutaneous absorption models to improve accuracy of evaluation of exposures to environmental contaminants.

Coulombe, H. N., S. H. Ridgway, and W. E. Evans. 1965. Respiratory Water Exchange in Two Species of Porpoise. *Science* **149**: 86-88.

The exhalations of the two species of porpoises examined contained less water vapor than those of terrestrial mammals. This is seen as an adaptation to conserve water in these animals which live in an environment where no fresh water is available.

Davis, R.W. and T.M. Williams. 1992. Effect of Water Temperature on Swimming Energetics in Sea Lions. (Abs.) *The Physiologist*. **35** (4): 176.

Reports on study of the effect of water temperature on swimming metabolic rate. Decreasing water temperature resulted in 38% increase in resting oxygen consumption, but no significant difference in swimming oxygen consumption. Results show energetic cost of swimming in sea lions is independent of water temperature between 5 and 30 deg. C.

Dawson, W. W., D. A. Carder, S. H. Ridgway, and E. T. Schmeisser. 1981. Synchrony of Dolphin Eye Movements and Their Power Density Spectra. *Comp. Biochem. Physiol.* **68A**:443-449.

Eye movements in the horizontal and vertical planes of a normal human and two bottlenosed dolphins were analyzed and compared. Although dolphin eyes are mobile at lower fundamental frequencies than in humans, there is a low level of synchrony between the two eyes.

Dawson, W. W., J. P. Schroeder, and J. F. Dawson. 1987. The Ocular Fundus of Two Cetaceans. *Marine Mammal Science.* **3**:1-13.

By use of a technique to correct the aerial myopia encountered in fundus photography of the marine mammal eye, the first high-quality photographs were obtained of the eyes of a living *Tursiops* and a *Grampus*.

Dawson, W. W., J. P. Schroeder, and S. N. Sharpe. 1987. Corneal Surface Properties of Two Marine Mammal Species. *Marine Mammal Science.* **3**:186-197.

Describes and compares the cornea of *Tursiops* and *Zalophus*. The results provide an explanation for the resolution of the *Zalophus* eye in air and water, but “the aerial acuity of *Tursiops* remains a mystery.”

Dawson, W. W., P. E. Nachtigall, J. C. Dawson, G. M. Hope, and J. P. Schroeder. 1992. Cetacean Lens-Zones of Discontinuity-Indices of Health and Development. *Marine Mammal Science*. **8** (4): 379-386.

Details of the eye lenses of two living bottlenose dolphins (*Tursiops truncatus*) and a Risso’s dolphin (*Grampus griseus*) were photographed. Spatially periodic stria could be visualized, with varying spaces between stria. Digitization of one photo allowed quantification of sizes and numbers of layers. Lens zone measurement may provide data on cetacean health and age.

Dawson, W. W., J. P. Schroeder, J. C. Dawson, and P. E. Nachtigall. 1992. Cyclic Ocular Hypertension in Cetaceans. *Marine Mammal Science*. **8** (2): 135-142.

Intraocular pressure (IOP) was measured in each eye of two adult *Tursiops truncatus* and one *Grampus griseus*. Measurements were made in alternation between eyes over a time span. Compared to humans, these cetaceans exhibit clinical ocular hypertension bilaterally. The range of pressures found, over time, was much greater than reported previously for several terrestrial mammals.

Demski, L. S., S. H. Ridgway, T. H. Bullock, and M. Schwanzel-Fukuda. 1985. Terminal Nerve of Odontocete Whales. *Amer. Zool.* **25**:107A.

See Ridgway et al., 1987, below.

Demski, L. S., S. H. Ridgway, and M. Schwanzel-Fukuda. 1990. The Terminal Nerve of Dolphins: Gross Structure, Histology and Lutenizing-Hormone-Releasing Hormone Immunocytochemistry. *Brain, Behavior and Evolution*. **36**:249-261.

The structure and cell type of the dolphin terminal nerves and ganglion are described. The cells that exhibit a response to lutenizing hormone releasing hormone antibody are figured and described in detail.

Dolphin, W.F., W.W.L. Au, P.E. Nachtigall, and J.L. Pawloski. 1995. Modulation Rate Transfer Functions to Low Frequency Carriers by Three Species of Cetaceans. *Jour. Comp. Physiol*. **177**: 235-245.

Modulation rate transfer functions were obtained from a false killer whale (*Pseudorca crassidens*), a beluga whale (*Delphinapterus leucas*) and a bottlenose dolphin (*Tursiops truncatus*) in a study of their auditory capabilities employing electrophysiological techniques. The vast majority of previous studies in this area employed psychophysical techniques.

Duffield, D. A., S. H. Ridgway, and R. S. Sparkes. 1967. Cytogenetic Studies of Two Species of Porpoise. *Nature* **213**:189-190.

The diploid chromosome number for a male and female *Tursiops truncatus* and for two males and one female *Lagenorhynchus obliquidens* was found to be 44. There were no obvious differences in the karyotypes of the two species.

Duffield, D. A., S. H. Ridgway, and L. H. Cornell. 1983. Hematology Distinguishes Coast and Offshore Forms of Dolphins (*Tursiops*). *Can. Jour. Zool.* **61**: 930-933.

Bottlenosed dolphins can be separated into coastal and offshore ecotypes based on hematologic values, the offshore forms having higher values. There appears to be a significant genetic basis for these differences.

Flanigan, N. J. 1965. Neuroanatomy of the Dolphin Spinal Cord. *Anat. Rec.* **151**:350.

Flanigan, N. J. 1966. The Anatomy of the Spinal Cord of the Pacific Whitesided Dolphin (*Langenorhynchus obliquidens*). In: *Whales, Dolphins. and Porpoises,* K.S. Norris (ed.). Univ. of Calif. Press, Berkeley, pp. 207-231.

Describes the anatomy of the spinal cord and discusses the possible significance of its distinctive features.

Flanigan, N. J. 1972. The Central Nervous System. In: *Mammals of the Sea—Biology and Medicine,* S. H. Ridgway (ed.). Chas. C. Thomas Publ., Springfield, IL, pp. 215-246.

Reviews present knowledge of the central nervous system of cetaceans and pinnipeds, including findings made by the author while working at the Navy's Marine Bioscience Facility.

Fong, M. L., R. M. Yamada, and W. A. Friedl. 1989. Post Exercise Skin Temperature and Heat Flux of Atlantic Bottlenosed Dolphins (*Tursiops truncatus*). (Abs.) Eighth Biennial Conf. on the Biology of Marine Mammals. Society of Marine Mammalogy, Pacific Grove, CA., p. 20.

Skin temperatures and heat flux were measured from two dolphins before and after controlled swimming. Different temperature and flux patterns occurred for the dolphins' bodies and fins.

Friedl, W. A., R. M. Yamada, M. L. Fong, and J. E. Haun. 1987. Physical Conditioning of Bottlenosed Dolphins for Bioenergetic Studies. (Abs.) Seventh Biennial Conf. on the Biology of Marine Mammals, Society of Marine Mammalogy, Miami, FL, p. 23.

Describes the equipment, training, and conditioning regime for a study to determine dolphin aerobic work capacity and swimming energy requirements.

Friedl, W. A., J. E. Haun, M. L. Fong, and R. M. Yamada. 1989. Aerobic Exercise by Bottlenosed Dolphins. (Abs.) Eighth Biennial Conf. on the Biology of Marine Mammals. Society of Marine Mammalogy, Pacific Grove, CA., p. 21.

Describes measurements of oxygen consumption and respiration rate for aerobic exercise at controlled levels. Results indicated short-term oxygen debts were incurred even for conditions seemingly within the dolphins' maximal aerobic capacity.

Friedl, W. A., P. E. Nachtigall, P. W. B. Moore, N. K. W. Chun, J. E. Haun, R. W. Hall, and J. L. Richards. 1990. Taste Reception in the Pacific Bottlenosed Dolphin (*Tursiops truncatus gilli*) and the California Sea Lion (*Zalophus californianus*). In: *Sensory Abilities of Cetaceans*, J. A. Thomas and R. A. Kastelein (eds.). Plenum Press, New York, pp. 447-454.

Abilities to detect sour, bitter, salty, and sweet substances in distilled water were tested. The dolphin detected all four tastes. The sea lion detected salty, sour and some bitter substances but not other bitter tastes or the sweet taste (sucrose). The study showed for the first time that bottlenosed dolphins can detect sweet substances and that California sea lions have gustatory senses.

Gilmartin, W. G., R. W. Pierce, and G. A. Antonelis, Jr. 1974. Some Physiological Parameters of the Blood of the California Gray Whale. *Mar. Fish. Rev.* **36** (4):28-31.

Hematocrit, oxyhemoglobin dissociation curve, and blood volume were determined, the last by isotopic techniques.

Green, R. F. 1972. Observations on the Anatomy of Some Cetaceans and Pinnipeds. In: *Mammals of the Sea--Biology and Medicine*, S. H. Ridgway (ed.). Chas. C. Thomas Publ., Springfield, IL, pp. 247-297.

Observations (with unique new illustrations) of cetacean and pinniped anatomy based primarily on dissections made by the author.

Greenwood, A. G., S. H. Ridgway, and R. J. Harrison. 1971. Blood Values in Young Gray Seals. *Jour. Am. Vet. Med. Assn.* **159** (5):571-574.

Red and white blood cell measurements, plasma electrolytes and serum proteins, and blood chemistry values are given.

Hamlin, R. L., S. H. Ridgway, and W. G. Gilmartin. 1972. Electrocardiogram of Pinnipeds. *Am. Jour. Vet. Res.* **33**(4):867-875.

Electrocardiograms obtained from California sea lions, elephant seals, and harbor seal are analyzed and discussed.

Harrison, R. J. and S. H. Ridgway, 1971. Gonadal activity in some bottlenosed dolphins (*Tursiops truncatus*). *Jour. Zool.* **165**:355-366.

Characteristics of the ovaries and testes of young and adult bottlenosed dolphins indicate that sexual maturity in females is probably reached in their fifth year. Males become sexually mature at an estimated age of 10 years. No evidence of regular cyclic ovulation was found.

Harrison, R. J. and S. H. Ridgway. 1975. Restrained and Unrestrained Diving in Seals. *Rapp. P. - v. Reun. Cons. Int. Explor. Mer.* **169**:76-80.

Cardiovascular response of gray seals was much higher during a forced dive than during an unrestrained trained dive. Cardiac rhythm also varied with different observed behaviors.

Harrison, R. J. and S. H. Ridgway. 1976. *Deep Diving Mammals*. 51 pp. Meadowfield Press Ltd., Durham, England.

A booklet reviewing what is known about deep diving in mammals, including depth and duration of dives, historical background, adaptations, other aspects of deep diving, and future deep diving by man.

Heath, M.E. and W.G. Miller. 1997. Physiological Responses to Encountering Warm Water in Bottlenose Dolphins. Experimental Biology Conf., New Orleans, LA, April 1997.

Study showed dolphins appear to have a highly adapted mechanism enabling the animal to redistribute body heat to the blubber layer resulting in a lower core temperature when exposed to warm water. This adaptation reduces the rate of heat gained from the environment and provides a margin of safety in the level of core temperature for dolphins encountering warm water conditions that may pose a heat stress.

Horvath. S. M., H. Chiodi, S. H. Ridgway, and S. Azar, Jr. 1968. Respiratory and Electrophoretic Characteristics of Hemoglobin of Porpoises and Sea Lions. *Comp. Biochem. Physiol.* **24**:1027-1033.

Porpoises that swim faster and dive longer and deeper have greater hemoglobin oxygen affinity than the slower swimming, shallower, and shorter diving species.

Hui, C. A. 1975. Thoracic Collapse as Affected by the Retia Thoracica in the Dolphin. *Resp. Physiol.* **25**:63-70 (Netherlands).

The carcass of a *Delphinus* was subjected to two simulated dives in a hyperbaric chamber to the equivalent of 69.7 m. In one dive, the thorax was in natural state; in the other, 100 ml of water had been injected into each pleural cavity. Results indicated that an engorged thoracicrete reduced the displacement stress on abdominal organs under pressures encountered in diving.

Hui, C. A. 1978. Reliability of Using Dentin Layers for Age Determination in *Tursiops truncatus*. A report to the Marine Mammal Commission. Nat'l Tech. Info. Serv. PB-288 444, 25 pp.

Discusses histology of the mammalian tooth, utility of using dentin layers for age determination, and findings from an examination of teeth from three *Tursiops*, two of known age. It is concluded that annual increments of dentin are visible and can be regular through 11 years. No correlation of dentin layering with food consumption patterns or innate biorhythms based on lunar cycles was found.

Hui, C. A. 1979. Correlates of Maturity in the Common Dolphin (*Delphinus delphis*). *Fish. Bull.* **77**:295-300.

Body weight and length, degree of bone fusion in flippers, dentine layers, testes weights, and ovarian scars in 87 *D. delphis* (which had died in tuna nets) were treated statistically to determine correlation with sexual maturity.

Hui, C. A. 1981. Seawater Consumption and Water Flux in the Common Dolphin (*Delphinus delphis*). *Physiol. Zool.* **54** (4) :430--440.

In two captive dolphins, total body water was found to be low (37 percent of total body weight), indicating a high fractional rate of water turnover, most of which is due to the permeability of the skin. Skin was shown to be impermeable to sodium, so the only sodium source is ingested sea water.

Jensen, E., W. Van Bonn, M. Beeler and S. Ridgway. 1995. Forestomach Acidity of *Tursiops truncatus*. 11th Biennial Conf. on the Biology of Marine Mammals, Orlando, FL, Dec. 14-18, p. 59.

Paper presenting normal forestomach acidity in pre- and post-prandial dolphins.

Kanwisher, J. W. and S. H. Ridgway. 1983. The Physiological Ecology of Whales and Porpoises. *Sci. Am.* **248** (6):110-120.

Discusses the particular physiologic adaptations evolved by cetaceans for living in the sea, notably the ability to dive deep for long periods. Unlike other marine organisms, which tend to move nutrients downward, oceanic marine mammals, through their fecal output near the surface, tend to move nutrients upward.

Ketten, D.R., J. Lien, S. Todd and S. Ridgway. 1994. Acoustic Damage in Whale Ears: Aging vs. Injury. *The Physiologist*. **37** (5): 10.1.

Cochlear structure of an old dolphin with hearing loss was analyzed for potential use as a model to reveal hearing loss in stranded animals.

Ketten, D.R., S. Ridgway, and G. Early. 1995. Apocalyptic Hearing: Aging, Injury, Disease, and Noise in Marine Mammal Ears. 11th Biennial Conf. on the Biology of Marine Mammals, Orlando, FL, Dec. 14-18, p. 94.

Describes work to correlate changes in marine mammal ear anatomy as a result of age, biological factors and noise.

Kulu, D. D., I. Veomett, and R. S. Sparkes. 1971. Cytogenetic Comparison of Four Species of Cetaceans. *Jour. Mammal.* **52** (4): 828-832.

The model chromosome number for the common dolphin, Amazon freshwater dolphin, Dall's porpoise, and killer whale is 44, the same as that in other cetaceans examined, with the exception of the sperm whale, which has 42. Karyotypes of the killer and sperm whales are otherwise similar. The possible significance of these findings is discussed.

Leatherwood, J. S., M. W. Deerman, and C. W. Potter. 1978. Food and Reproductive Status of Nine *Tursiops truncatus* from the Northeastern United States Coast. *Cetology*, No. 28, 6 pp.

The nine dolphins (six stranded, three entangled in a fishing net) were examined for age, reproductive status, and stomach contents. Stomachs contained a predominance of Atlantic croakers, sea trout, and spot.

Lowell, W. R. and W. F. Flanigan, Jr. 1978. Chemoreception in Marine Mammals: A Review of the Literature. NOSC TR 353, 19 pp.

Discusses anatomical and physiological correlates and behavioral and ecological considerations of olfaction and gustation in cetaceans, pinnipeds, sea otters, and sirenians, followed by a bibliography.

Lowell, W.R. and W.F. Flanigan, Jr. 1980. Marine Mammal Chemoreception. *Mammal. Rev.*, 1980:1053-1059.

Later version of previous publication.

Malvin, R. L., J. P. Bonjous, and S. H. Ridgway. 1971. Antidiuretic Hormone Levels in Some Cetaceans. Soc. Exp. Biol. and Med. **136** (4):1203-1205.

Data on renal function in the bottlenosed dolphin and killer whale are presented and discussed.

Malvin, R. L., S. H. Ridgway, and L. Cornell. 1978. Renin and Aldosterone Levels in Dolphins and Sea Lions. Soc. Exper. Biol. and Med. **157**:665-668.

A significant correlation between plasma renin activity (PRA) and concentration of aldosterone in plasma was found in both dolphins and sea lions. An excellent correlation between urinary sodium excretion and PRA was also obtained in two dolphins. These data support the hypothesis that in marine mammals the reninangio-tensionaldosterone axis plays a role in the regulation of salt balance.

McCormick, J. G., E. G. Wever, J. L. Mattsson, and S. H. Ridgway. 1977. Anatomical and Physiological Adaptations of Marine Mammals for the Prevention of Diving induced Middle-ear Barotrauma and Round Window Fistula. *Undersea Biomedical Research* **4** (1): A 42.

Comparative marine mammal experience helped make a preoperative diagnosis of diving-induced round window fistula in a human patient.

Nachtigall, P. E. and R. W. Hall. 1984. Taste Reception in the Bottlenosed Dolphin. *Acta Zoo. Fennica* **172**:147-148.

A dolphin's taste thresholds for citric acid (sour) and quinine sulfate (bitter) were found to be just above the human thresholds for these substances.

Nachtigall, P. E. 1986. Vision, Audition, and Chemoreception in Dolphins and Other Marine Mammals. In: *Dolphin Cognition and Behavior*, R. J. Schusterman, J. A. Thomas, and F. G. Wood (eds.). Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 79-113.

A review of what is known about sensory capabilities in dolphins, pinnipeds, and sea otters (vision only).

Nachtigall, P. E. 1989. Risso's Dolphin (*Grampus griseus*) Vision. (Abs.) Eighth Biennial Conf. on the Biology of Marine Mammals, Society of Marine Mammalogy, Pacific Grove, CA., p. 45.

See Nachtigall, 1989, below.

Nachtigall, P. E. 1989. Visual Acuity of the Risso's Dolphin (*Grampus griseus*) in Air. (Abs.) Bulletin of the Psychonomic Society **27** (6):502.

Visual acuity, in terms of minimum angle of resolution, was measured using a two-alternative forced-choice procedure.

Nachtigall, P. E. and J. L. Pawloski. 1991. Aerial Visual Acuity of the Risso's Dolphin at Two Distances. (Abs.) Bulletin of the Psychonomic Society **29** (6):528.

Visual acuity, in terms of minimum angle of resolution, was measured at distances of 1 and 2.5 meters. Resolution was found to be better at 2.5 meters than at 1 meter.

Pabst, D.A., S.A. Rommel, W.A. McLellan, T.M. Williams and T.K. Rowles. 1995. Thermoregulation of the Intra-Abdominal Testes of the Bottlenose Dolphin (*Tursiops truncatus*) During Exercise. *Jour. Exp. Biology*. **198**: 221-226.

A special rectal probe measured colonic temperatures simultaneously before and immediately after vigorous swimming. The results suggested the dolphin's countercurrent heat exchanger has an increased ability to cool arterial blood supply to the testes during swimming. Believed to be first report of deep body cooling in an exercising mammal that is not diving.

Pepper, R. L. and J. V. Simmons, Jr. 1973. In-air Visual Acuity of the Bottlenosed Dolphin. *Exper. Neur.* **41** (2):271-276.

Horizontal-black and white-line gratings were presented in a successive discrimination task. Over a constant viewing distance of 2.8 meters, a minimal visual angle of 18 minutes of arc was obtained.

Ridgway, S. H., and D. G. Johnston. 1966. Blood Oxygen and Ecology of Porpoises of Three Genera. *Science* **151** (3709):456--458.

The total blood-oxygen content of the highly active, deep-diving Dall's porpoise is almost three times that of the coastal dwelling bottlenosed. The pelagic white-sided dolphin, less active than the Dall, is intermediate. Heart weight of the Dall's porpoise is about 140 percent that of the bottlenosed.

Ridgway, S. H., B. L. Scronce, and J. Kanwisher. 1969. Respiration and Deep Diving in the Bottlenosed Porpoise. *Science* **166**:1651-1654.

A porpoise was trained to dive on command to depths down to 300 meters, then provide a lung air sample at the surface before breathing. It was also trained to swim between divers at 20 meters and to breath-hold at the surface for deep-dive time equivalents. Analyses of oxygen and carbon dioxide were then compared for the three situations.

Ridgway, S. H., J. G. Simpson, G. S. Patton, and W. G. Gilmartin. 1970. Hematologic Findings in Certain Small Cetaceans. *Jour. Am. Vet. Med. Assn.* **157**:566-575.

Clinical laboratory data on the blood of small cetaceans were collected from representatives of a number of species.

Ridgway, S. H. 1971. Buoyancy Regulation in Deep Diving Whales. *Nature* **232** (5306): 133-134.

Comments on a suggestion that the spermaceti organ of sperm whales serves as a buoyancy regulator in deep dives. Evidence is presented that this hypothesis is incorrect.

Ridgway, S. H. and G. S. Patton. 1971. Dolphin Thyroid: Some Anatomical and Physiological Findings. Z. *vergl. Physiol.* **71**:129-141.

Research conducted with representatives of four species of delphinids was directed toward elucidating the function of this organ in toothed cetaceans. Biochemical data on thyroid hormones are presented. All animals examined had larger thyroids than terrestrial mammals of comparable weight.

Ridgway, S. H. 1972. Homeostasis in the Aquatic Environment. In: *Mammals of the Sea—Biology and Medicine*, S. H. Ridgway (ed.). Chas. C. Thomas Publ., Springfield, FL, pp. 590-747.

Account of marine mammal research conducted by the author in the areas of diving physiology, water balance, reproductive physiology, hematology, and blood chemistry, husbandry, behavior, and animal health (including anesthesia).

Ridgway, S. H. 1973. Control Mechanisms in Diving Dolphins and Seals. Doctoral Thesis, University of Cambridge, 90 pp. with appendices.

Primarily on diving physiology of dolphins, sea lions, and seals (especially the gray seal), but also includes research on hearing, sleep, and brain temperatures in the gray seal.

Ridgway, S. H., J. G. McCormick, and E. G. Wever. 1974. Surgical Approach to the Dolphin's Ear. *Jour. Exp. Pathol.* **188** (3):265-276.

Describes anesthesia procedure, surgical techniques, and physiological monitoring for making electrophysiological measurements at the cochlea.

Ridgway, S. H., D. A. Carder, and W. Clark. 1975. Conditioned Bradicardia in the Sea Lion (*Zalophus californianus*). *Nature* **256** (5512):37-38.

Slowing of heart rate was achieved by conventional conditioning techniques.

Ridgway, S. H. 1976. Diving Mammals and Biomedical Research. *Oceanus* **19** (2):49-55.

Describes biomedical research conducted with the California sea lion, gray seal, common seal, elephant seal, Weddell seal, and bottlenosed dolphin.

Ridgway, S. H. and R. H. Brownson. 1979. Brain Size and Symmetry in Three Dolphin Genera. *Anat. Rec.* **193**:664.

Asymmetries of weight and surface area of cerebral cortex between right and left hemispheres were found in *Tursiops* and *Delphinus*, but no significant asymmetries were found in *Stenella*. Average body and brain weights, lengths, and cortical surface areas are given for 13 *Tursiops*, 9 *Delphinus*, and 11 *Stenella*.

Ridgway, S. H. and R. Howard. 1979. Dolphin Lung Collapse and Intramuscular Circulation During Free Diving: Evidence from Nitrogen Washout. *Science* **206**:1182-1183.

Intramuscular nitrogen tensions in *Tursiops* after repetitive ocean dives suggested that lung collapse occurs at a depth of about 70 meters and that intramuscular circulation is maintained during unrestrained diving in the open sea. The dolphin is not protected by lung collapse in dives shallower than 70 meters.

Ridgway, S. H., T. H. Bullock, D. A. Carder, R. L. Seeley, D. Woods, and R. Galambos. 1981. Auditory Brainstem Responses in Dolphins. *Proc. Natl. Acad. Sci.* **78** (3):1943-1947.

Auditory brainstem response (ABR) in two *Tursiops* and two *Delphinus* were compared with human and rat ABR data. The ABR can be used to test theories of dolphin sonar signal processing and permits rapid evaluation of hearing thresholds. Audio-metric information on stranded or trapped giant whales might be obtained by using the ABR.

Ridgway, S. H. and C. A. Fenner. 1982. Weight-Length Relationships of Wild-Caught and Captive Atlantic Bottlenosed Dolphins. *Jour. Am. Vet. Med. Assn.* **181** (11):1310-1315.

From weight and length measurements of 144 dolphins, guidelines were established for use in estimating whether a dolphin is over or underweight.

Ridgway, S. H., C. A. Bowers, D. Miller, M. L. Schultz, C. A. Jacobs, and C. A. Dooley. 1984. Diving and Blood Oxygen in the White Whale. *Canadian Jour. Zool.* **62** (11): 2349-2351.

White whales, trained to dive on command in the open sea, remained submerged as long as 15 minutes 50 seconds and dove as deep as 647 meters (2122 feet).

Ridgway, S. H. and R. H. Brownson. 1984. Relative Brain Sizes and Cortical Surface Areas in Odontocetes. *Acta Zool. Fennica* **172**:149-152.

Surface area of the cerebral cortex was found to be directly related to brain weight in a variety of odontocetes, but the genera differed greatly when cortical area and brain weight were related to body length and weight and to encephalization quotient. Includes findings on brains of neonates and on brain asymmetries.

Ridgway, S. H. 1985. The Bends Problem: Dolphins, Seals, and Nitrogen. (Abs.) Sixth Biennial Conf. on Biology of Marine Mammals, Society of Marine Mammalogy, Vancouver, B. C., Canada, Nov. 22-26, p. 102.

Reviews and compares findings from diving studies on dolphins and seals. Dolphin breath-hold time is shorter, but they dive faster and seem capable of more deep dives in rapid succession.

Ridgway, S. H. 1986. Diving Responses. Letter to the Editor: Reply to R. Elsner. *Marine Mammal Science* **2** (4):326-328.

Discusses the so-called "diving responses." Proposes more specific terminology for the physiological processes involved.

Ridgway, S. H. 1986. Diving Dolphins. In: *Research on Dolphins*, M. M. Bryden and Richard Harrison (eds.). Oxford Univ. Press, New York, pp.33-58.

Includes historical background on depth-of-dive inferences and observations, modern studies, hazards of diving, respiration, bradycardia, and species differences with respect to metabolism, blood volume, and blood oxygen capacity.

Ridgway, S. H. 1986. Dolphin Brain Size. In: *Research on Dolphins*, M. M. Bryden and R. J. Harrison (eds.). Oxford Univ. Press, New York, pp. 59-70.

Discusses absolute brain sizes in cetaceans; the various cephalization coefficient concepts, including Jerison's "encephalization quotient," here applied to cetaceans; growth of the brain; fissurization; volume of the dolphin cortex; and asymmetry of the dolphin brain.

Ridgway, S. H. 1986. Physiological Observations on Dolphin Brains. In: *Dolphin Cognition and Behavior,* R. J. Schusterman, J. A. Thomas, and F. G. Wood (eds.). Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 31-59.

Discusses anatomical and physiological characteristics of dolphin brains, including size, convolutedness, cortex volume, metabolism, hemispheric independence, lateralization, and auditory areas.

Ridgway, S. H. 1986. Diving in Cetaceans. In: *Diving in Animals and Man*, A.O. Brubakk, J. W. Kanwisher, and G. Sundness (eds.). The Norwegian Society of Science and Letters, Trondheim, Norway, pp. 33-62.

A comprehensive account, including known diving capabilities of 10 cetaceans, techniques used to study diving, physiological and anatomical hazards of diving, adaptations for diving, sound production and diving, metabolism and diving, oxygen stores, and bradycardia.

Ridgway, S.H. 1987. The Cetacean Central Nervous System. In: *Encyclopedia of Neuroscience*, Vol. I, G. Adelman (ed.). Birkhauser, Boston, pp.220-225.

The author writes a concise review of what is known about the cetacean central nervous system with special emphasis on anatomy and physiology.

Ridgway, S. H., L. S. Demski, T. H. Bullock, and M. Schwanzel-Fukuda. 1987. The Terminal Nerve in Odontocete Cetaceans. *Ann. New York Acad. Sci.* **519**:201-212.

Terminal nerves accompany olfactory nerves in many vertebrate species. Olfactory nerves are completely absent, however, in adult odontocetes, but large, myelinated terminal nerves persist. Five odontocete species were studied in detail; the terminal nerves observed were the largest ever reported. The possible chemosensory function of the terminal nerve in odontocetes is discussed.

Ridgway, S. H. 1988. The Cetacean Central Nervous System. In: *Comp. Neuroscience and Neurobiology*. Birkhauser, Boston **1**:20-25.

Current knowledge on the anatomy and physiology of the central nervous system of whales, dolphins, and porpoises is reviewed.

Ridgway, S. H. and F. G. Wood. 1988. Cetacean Brain Evolution. *Behav. and Brain Sci.* **11** (1): 99-100.

Comment on review article. Presents facts on absolute and relative sizes of cetacean brains. Discusses evolutionary aspects of cetacean brain development and cites relevant literature.

Ridgway, S. H. 1989. The Central Nervous System of the Bottlenosed Dolphin. In: *The Bottlenosed Dolphin, Tursiops spp.*, J. S. Leatherwood and R. Reeves (eds.). Academic Press, San Diego, CA, pp. 69-97.

Current knowledge on the brain of the bottlenosed dolphin (*Tursiops truncatus*) is reviewed. Photographs and drawings illustrate various features of the brain.

Ridgway, S. H. and D. A. Carder. 1990. Tactile Sensitivity, Somatosensory Responses, Skin Vibrations, and the Skin Surface Ridges of the Bottlenosed Dolphin (*Tursiops truncatus*). In: *Sensory Abilities of Cetaceans*, J. A. Thomas and R. A. Kastelein (eds.). Plenum Press, New York, pp. 163-179.

The dolphin's skin sensitivity was studied through the use of electrophysiological techniques. A map of skin sensitivity is presented and skin anatomy is discussed with special consideration of the cutaneous ridges and muscle underlying the skin.

Ridgway, S., M. Reddy, T. Kamolnick, D. Skaar and C. Curry. 1992. Calorie Consumption of Growing Adult, Pregnant, and Lactating Tursiops. 23rd Annual Conf. of the International Association for Aquatic Animal Medicine, Hong Kong, May 18-22, 1992, **23**: 44.

Calorie consumption required for *Tursiops truncatus* at various stages of life were measured and presented along with graphs showing the reduction in calorie consumption as the dolphin ages.

Ridgway, S.H., T. Kamolnick, M. Reddy, and C. Curry. 1993. Re-lactation by 30+ year-old *Tursiops* After Suckling by Unrelated Orphan Calves. 24th Annual Conf. of the International Association for Aquatic Animal Medicine. Chicago, IL, May 16-20, **24**:105.

Report of two cases where suckling by unrelated calves resulted in milk production in two mature female bottlenose dolphins, *Tursiops truncatus*.

Ridgway, S.H. and R.J. Tarpley. 1995. Brain Mass Comparisons in Cetacea. Society for Neuroscience. **21** (1):433.

Presents data on more than 1000 cetacean brains. Different groups are compared, showing that the largest brains are found among the family Delphinidae.

Ridgway, S.H. and S. Kohin. 1995. The Relationship Between Heart Mass and Body Mass for Three Cetacean Genera: Narrow Allometry Demonstrates Interspecific Differences. *Marine Mammal Science*. **11** (1):72-80.

A narrow scale allometric analysis demonstrated significant differences in the scaling of heart mass with body mass in three cetacean genera--*Phocoenoides dalli, Lagenorhynchus obliquidens* and *Tursiops truncatus*—that may be due to differences in physiologic and ecological demands.

Ridgway, S.H. and R.J. Tarpley. 1996. Brain Mass Comparisons in Cetacea. 27th Annual Conf. of the International Association for Aquatic Animal Medicine, Chattanooga, TN, May 11-15. **27**:55.

See Ridgway and Tarpley, 1995, above.

Romano, T. and D.L. Felten. 1988. Neural-Immune Interactions--A Potential Area of Investigation for Marine Mammals. 19th Annual Conf. of the International Association for Aquatic Animal Medicine, Baltimore, May 22-26, 1988, **19**:68.

Discusses potential application of neural-immune interactions to marine mammals.

Romano, T., D.L. Felten, and J.A. Olschowka. 1989. Neural-Immune Interactions in the Beluga Whale. 20th Annual Conf. of the International Association for Aquatic Animal Medicine, San Antonio, TX, May 14-19, 1989, **20**:82.

Demonstrates anatomical pathways linking the nervous and immune systems in the beluga.

Romano, T., D.L. Felten, J.A. Olschowka and S.Y. Felten. 1991. The Demonstration of a Possible Link for Neural-Immune System Interactions in the Beluga Whale. (Abs.) *Society of Neuroscience Abstracts*. **17** (1):833.

Demonstrates innervation of white whale or beluga lymphoid organs such as spleen, lymph nodes and thymus.

Romano, T., J.A. Olschowka, S.Y. Felten, and D.L. Felten. 1991. Neural-Immune Interactions in the Beluga Whale. (Abs.) *Society of Neuroscience Abstracts*. **17** (1):833.

Discusses the interaction of the nervous and immune systems in the beluga whale.

Romano, T., J.A. Olschowka, S.Y. Felten and D.L. Felten. 1992. Communication of Nervous and Immune Systems in the Beluga, *Delphinapterus leucas*. 23rd Annual Conf. of the International Association for Aquatic Animal Medicine, Hong Kong, May 18-22, 1992, **23**:97.

Discusses neural-immune interactions in the beluga.

Romano, T.A., S.H. Ridgway and V. Quaranta. 1992. MHC Class II Molecules and Immunoglobulins on Peripheral Blood Lymphocytes of the Bottlenosed Dolphin, *Tursiops truncatus*. *Jour. Exper. Zoology*. **263**: 96-104.

Describes the distribution of class II molecules and surface immunoglobulins on dolphin peripheral blood lymphocytes.

Romano, T.A., S.Y. Felten, J.A. Olschowka and D.L. Felten. 1993. A Microscopic Investigation of the Lymphoid Organs of the Beluga, *Delphinapterus leucas*. *Jour. Morphology*. **215**:261-287.

Investigates morphology of white whale or beluga lymphoid organs. This is the first ever comprehensive description of lymphoid organs from the white whale.

Romano, T., S.Y. Felten, J.A. Olschowka and D.L. Felten. 1993. General Morphology and Innervation of the Lymphoid Organs in the Beluga, *Delphinapterus leucas*. 24th Annual Conf. of the International Association for Aquatic Animal Medicine, Chicago, IL, May 16-20, **24**:111.

Discusses the morphology and innervation of white whale or beluga lymphoid organs such as spleen, lymph nodes and thymus.

Romano, T., D.L. Felten, S.Y. Felten and J.A. Olschowka. 1993. An Anatomical Link Between the Nervous and Immune Systems in the Beluga, *Delphinapterus leucas*. Tenth Biennial Conf. on the Biology of Marine Mammals, Galveston, TX, Nov. 11-15, 1993, p. 6.

Investigates neural-immune interactions in the white whale or beluga, with special reference to the anatomy of the nervous system and organs involved in the immune system.

Romano, T.A., S.Y. Felten, J.A. Olschowka and D.L. Felten. 1994. Noradrenic and Peptidergic Innervation of Lymphoid Organs in the Beluga, *Delphinapterus leucas*: An Anatomical Link Between the Nervous and Immune Systems. *Jour. Morphology*. **21**:243-259.

Investigates the innervation of the white whale or beluga lymphoid organs and demonstrates a pathway for potential communication between the nervous and immune system.

Romano, T.A., S. H. Ridgway and S.N. Haber. 1995. The Basal Ganglia of the White Whale, *Delphinapterus leucas*: A Comparative Study. *Society of Neuroscience Proceedings*. **21** (1):155.

Investigates basal ganglia of the white whale in comparison with other species.

Rommel, S.A., D.A. Pabst, W.A. McLellan, T.M. Williams and W.A. Friedl. 1994. Temperature Regulation of the Testes of the Bottlenose Dolphin (*Tursiops truncatus*): Evidence from Colonic Temperatures. *Jour. Comp. Physiol. B* **164**: 130-134.

A specially designed rectal probe measured temperatures simultaneously in several positions in the region of the colon. These support the hypothesis that cooled blood from peripheral sites (dorsal fin and flukes) is introduced into the deep abdominal cavity and functions to regulate the temperature of arterial blood flow to the dolphin testes. This has implications for the reproductive success of active males exposed to tropical or warm water conditions.

St. Aubin, D.J., S.H. Ridgway and R.S. Wells. 1991. Thyroid Hormone Metabolism in Small Odontocetes. Ninth Biennial Conf. on the Biology of Marine Mammals, Dec. 5-9, Chicago, IL, p. 66.

Aspects of thyroid hormone (YH) balance were examined in captive and free-ranging beluga whales, *Delphinapterus leucas,* and bottlenose dolphins, *Tursiops truncatus*.

St. Aubin, D.J., S.H. Ridgway, R.S. Wells, and H. Rhinehart. 1996. Dolphin Thyroid and Adrenal Hormones: Circulating Levels in Wild and Semidomesticated *Tursiops truncatus*, and Influence of Sex, Age, and Season. *Marine Mammal Science*. **12** (1):1-13.

Biological and environmental influences on circulating adrenal and thyroid hormones were investigated in 36 wild and 36 semidomesticated Atlantic bottlenosed dolphins, *Tursiops truncatus*, matched by age, sex, and time of year when the samples were collected. Levels of both cortisol and aldosterone were low in semidomesticated dolphins conditioned to present voluntarily their tails for blood sampling, an approach that appears to yield specimens representative of resting values for these constituents.

Shaffer, S.A., T.M. Williams and D.P. Costa. 1995. Blood Plasma Lactate and Glucose of a Freely Diving Bottlenose Dolphin (*Tursiops gilli*). (Abs.) 11th Biennial Conf. on the Biology of Marine Mammals, Orlando, FL, Dec. 14-18, p. 103.

An open-ocean trained dolphin dove repeatedly to depths of 60 and 140 meters, returning to the surface for blood sampling after each dive series. Samples showed post-dive lactate increase and a slight glucose increase, but no correlation of either with dive duration. Results indicate lactate increase may have been caused by the swimming effort and/or inter-dive recovery time.

Shaffer, S.A., D.P. Costa, and T.M. Williams. 1996. Exercise Performance of White Whales (*Delphinapterus leucas*). (Abs.) *The Physiologist*. **39** (5): A62.

Swimming behavior, respiration rates and blood chemistry of two white whales were studied during and post exercise by transit swimming next to a boat. Respiration rates decreased significantly as locomotor speed increased, contrasting sharply to terrestrial mammals during exercise. Observed blood chemistry (marked increases in blood plasma lactate, slight glucose decrease) and respiration rate changes indicate high speed swimming at the surface is costly.

Shaffer, S.A. 1996. Assessment of Physiological and Behavioral Adjustments in Diving and Exercise of Two Cetacean Species, *Delphinapterus leucas* and *Tursiops gilli*. Thesis, University of California Santa Cruz, 92 pp.

Diving profiles with oxygen stores and predictions of aerobic dive limits in two free-diving white whales.

Shoemaker, P. A. and S. H. Ridgway. 1991. Cutaneous Ridges in Odontocetes. *Marine Mammal Science* **7**(1):66-74.

The authors took surface impressions of dolphin skin to quantify the tiny cutaneous ridges that run circumferentially around the body from head to dorsal fin. They suggest that the ridges may have some function in the sense of touch and in the hydro-dynamic characteristics of the animal.

Simpson, J. G., W. G. Gilmartin, and S. H. Ridgway. 1970. Blood Volume and Other Hematologic Values in Young Elephant Seals (*Mirounga angustirostris*). *Am. Jour. Vet. Res.* **31**(8):1449-1452.

A mean blood volume of 216 ml/kg and a mean packed cell volume of 64 percent were found. The elephant seal, with the mean blood volume representing 20 percent or more of body weight, has the highest reported blood volume of any mammal.

Simpson, J. G. and M. B. Gardner. 1972. Comparative Microscopic Anatomy of Selected Marine Mammals. In: *Mammals of the Sea—Biology and Medicine*, S. H. Ridgway (ed.). Chas. C. Thomas Publ., Springfield, IL, pp. 298-418.

Profusely illustrated paper on the histology of organs and systems in certain cetaceans and pinnipeds, with emphasis on pathology.

Stromberg, M. W. 1985. Fat Distribution in the Skin of Bottlenosed Dolphins (*Tursiops truncatus* and *Tursiops gilli*). *Jour. Morphology* **186** (3): 315-326.

Fat was rather evenly distributed in all strata of the epidermis. Unique extracellular fat droplets were observed among the collagen bundles of the dermis and unusual lipid particles were in some vessels of the dermal papillae. A unique extracellular transport of dermal lipids to the epidermis is postulated. Possible functions of epidermal lipids are discussed.

Stromberg, M. W. 1989. Dermal-epidermal Relationships in the Skin of the Bottlenosed Dolphin (*Tursiops truncatus*). *Jour. Vet. Med.*, Series C: Anat. Histol. Embryol. **18**:1-13.

Dolphin skin was studied by a variety of methods. The arrangement of dermal and corresponding epidermal structure is described. Distinct epidermal pegs were not observed. Results are compared with information in recent literature. Apparent conflicts are discussed. The structure and scale of epidermal ridges are detailed.

Sweeney, J. C. 1974. Radiographic Atlas of the California Sea Lion. NUC TP 387, 16 pp.

A radiographic reference atlas with an evaluation of techniques for all of the standard positions. Includes photographs and drawings of the normal radiographic anatomy.

Tarpley, R. J. and S. H. Ridgway. 1991. Orbital Gland Structure and Secretions in the Atlantic Bottlenosed Dolphin (*Tursiops truncatus*). *Jour. Morphology* **207**:1-12.

The anatomy of the orbital gland that surrounds the dolphin’s eye was elucidated in numerous drawings, photographs, and photomicrographs. The gland secretes the visco-elastic tear secretion of dolphins and some of the properties of this secretion are discussed.

Tarpley, R.J. and S.H. Ridgway. 1991. Correlations of Corpus Callosum Size in Odontocete Cetaceans. (Abs.) *Society for Neuroscience Abstracts*. **17**: 257.13.

The midsagittal surface area of the corpus callosum was determined by computer-assisted morphometer in four odontocete cetacean families (Delphinidae, Monodontidae, Physeteridae and Ziphiidae) and correlated with brain weight and cerebral cortical surface area.

Tarpley, R.J., J.B. Gelderd, S. Bauserman and S.H. Ridgway. 1994. Dolphin Peripheral Visual Pathway in Chronic Unilateral Ocular Atrophy: Complete Decussation Apparent. *Jour. Morphology*. **222**:91-102.

Provides anatomical documentation and both light and electron microscopy employing special staining, demonstrating the fibers from each dolphin eye are directed to the opposite cerebral hemisphere.

Tarpley, R.J. and S.H. Ridgway. 1994. Corpus Callosum Size in Delphinid Cetaceans. *Brain, Behavior and Evolution*. **44**:156-165.

Measurements of corpus callosum size in a group of animals from different cetacean species demonstrate that the corpus callosum, the large bundle of nerve fibers that connect the two cerebral hemispheres, is relatively small compared to total brain size.

Wever, E. G., J. G. McCormick, J. Palin, and S. H. Ridgway. 1971. The Cochlea of the Dolphin (*Tursiops truncatus*): Hair Cells and Ganglion Cells. *Proc. Nat. Acad. Sci. USA* **68** (12):2908-2912.

The large number of hair cells found suggests a high order of auditory proficiency, and the large ratio of ganglion cells to hair cells suggests an unusual ability to utilize auditory information.

Wever, E. G., J. G. McCormick, J. Palin, and S. H. Ridgway. 1971. The Cochlea of the Dolphin (*Tursiops truncatus*): General Morphology. *Proc. Nat. Acad. Sci. USA* **68** (10): 2381-2385.

Describes the microscopic structure of the cochlea and discusses features believed to represent adaptations for the reception of high-frequency sounds.

Wever, E. G., J. C. McCormick, J. Palin, and S. H. Ridgway. 1971. Cochlea of the Dolphin (*Tursiops truncatus*): The Basilar Membrane. *Proc. Nat. Acad. Sci. USA* **68** (11): 2708-2711.

Describes the microscopic structure of the basilar membrane and notes features suggesting unusual capabilities of pitch discrimination at very high frequencies.

Williams, T.M., W.A. Friedl, and J.E. Haun. 1991. Swimming by Bottlenose Dolphins (*Tursiops truncatus*): Odontocete Olympians or Sedentary Cetaceans? (Abs.) Ninth Biennial Conf. on the Biology of Marine Mammals, Chicago, IL, Dec. 5-9, p. 74.

Reports on assessment of aerobic and anaerobic energetic costs for swimming dolphins, measured through heart rate, respiratory rate and post-exercise blood lactate concentration.

Concludes dolphins are capable of maintaining high work loads during static exercise. Routine swimming is energetically inexpensive.

Williams, T.M., J.E. Haun, W.A. Friedl, R.W. Hall, and L.W. Bivens. 1991. Assessing the Thermal Limits of Bottlenose Dolphins: A Cooperative Study by Trainers, Scientists, and Animals. Annual IMATA Conf., Vallejo, CA, Nov. 4-8, 1991.

Discusses a study of the thermoregulatory physiology of adult bottlenose dolphins (*Tursiops truncatus*) to determine the range of thermally neutral water temperatures for these cetaceans.

Williams, T.M., W.A. Friedl, and J.E. Haun. 1992. Assessing the Physiological limits of Exercise Performance in Bottlenose Dolphins. (Abs.) *The Physiologist*. **35** (4): 224.

Examines the relationship among aerobic and anaerobic costs of exercise, oxygen stores and level of effort in swimming and diving bottlenose dolphins (*Tursiops truncatus*). The dolphin's dynamic metabolic scope and level of maximal oxygen consumption fell short of those reported for elite terrestrial athletes such as horses and dogs. Oxygen stores were an important avenue of metabolic support during diving and swimming at routine speeds.

Williams, T.M., W.A. Friedl, and J.E. Haun. 1993. The Physiology of Bottlenose Dolphins (*Tursiops truncatus*): Heart Rate, Metabolic Rate and Plasma Lactate Concentration During Exercise. *Jour. Exp. Biol.* **179**: 31-46.

Study examined physiological responses and locomotor Energetics of two exercising adult *Tursiops*, measuring three indicators (heart rate, etc.) for the animals while pushing against a load cell and swimming next to a boat. Concludes the energetic cost of swimming for *Tursiops* is low in comparison to that of other aquatic and semi-aquatic mammals.

Williams, T.M., R.W. Davis, M.A. Castellini, T.R. Loughlin, D.G. Calkins and J. Sease. 1993. The Relationship Between Body Condition and Thermoregulatory Costs in Steller Sea Lion Pups. (Abs.) Tenth Biennial Conf. on the Biology of Marine Mammals, Galveston, TX, Nov. 11-15, p. 17.

Reports on examination of the quality and quantity of blubber in Steller sea lion pups and its effect on heat loss and thermal costs. Differences were determined in blubber thickness (coincident with body mass) and insulation quality and in thermal energetic costs between pups from rookeries on different islands.

Williams, T.M., S.F. Shippee, and M.J. Rothe. 1996. Strategies for Reducing Foraging Costs in Dolphins. In: *Aquatic Predators*, S. Greenstreet and M.L. Tasker (eds.) Blackwell Science Ltd., London, pp. 4-9.

Discusses a study of energetic costs associated with, and restricting time for, foraging. This effort addresses energy costs of locomotion, thermoregulation and digestion for bottlenose dolphins (*Tursiops truncatus*) and concludes their behaviors to reduce these costs benefit foraging animals by conserving limited oxygen reserves during a dive.

Woods, D. L., S. H. Ridgway, and T. H. Bullock. 1986. Middle- and Long-Latency Auditory Event-Related Potentials in Dolphins. In: *Dolphin Cognition and Behavior*, R. J. Schusterman, J. A. Thomas, and F. G. Wood (eds.). Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 61-77.

In recordings of event-related potentials in response to a variety of auditory stimuli, certain responses suggested a more precise representation of auditory stimuli in short-term memory in dolphins than in humans. Infrequent “deviant” stimuli produced a component similar in some respects to the “decision-related” P300 wave in humans.

4. HEALTH CARE/NUTRITION/PATHOLOGY

Beleau, M. H. and W. G. Gilmartin. 1974. Antibiotic Serum Levels in Porpoises. *Am. Zoo Vets. Annual Proceedings*, pp. 119-127.

Serum levels of antibiotics commonly used in porpoises were determined.

Buck, C. D. and J. P. Schroeder. 1990. Public Health Significance of Marine Mammal Diseases. In: *Handbook of Marine Mammal Medicine: Health, Disease, and Rehabilitation*, L.A. Dierauf (ed.). CRC Press, Cleveland, OH, pp. 163-173.

A review of reported cases of humans infected with micro-organisms acquired from direct contact with various marine mammals is presented.

Cartee, R.E., B.W. Gray, J. John and S.H. Ridgway. 1995. B-Mode Ultrasound Evaluation of Dolphin Skin. *Jour. Diagnostic Medical Sonography*. **11**: 76-80.

Skin specimens from 10 dolphins were studied with B-mode ultrasonography. The epidermal and hypodermal layers were defined, measured, and compared with measurements of actual tissue and with histologic measurements. B-mode measurements were found to be accurate and to provide visually acceptable information for evaluating health status of these animals. The detection of a skin parasite by B-mode ultrasonography is also presented.

Cartee, R.E., R. Tarpley, K. Mahoney, S.H. Ridgway and P.L. Johnson. 1995. A Case of Cystic Adrenal Disease in a Common Dolphin (*Delphinus delphis). Jour. Zoo and Wildlife Medicine*. **26** (2): 293-297.

Bilateral adrenal cysts were discovered in a common dolphin during a routine necropsy. The dolphin appeared to be a mature female with immature reproductive structures. The adrenals were removed, scanned ultrasonographically, sectioned, and stained. The occurrence of adrenal cysts in humans and other animals is reviewed.

Castellini, M.A. and T.M. Williams. 1993. Blood Chemistries and Body Condition of Steller Sea Lion Pups at Marmot Island, Alaska. *Marine Mammal Science* **9** (2): 202-208.

As part of a project assessing blood chemistry and body condition of pinnipeds in and around Alaskan waters, this effort studied whether declining Steller sea lion population might be attributable to significant metabolic disorders. Four indicators of such disorders are addressed: hydration state, blood metabolic chemistry, blood oxygen transport and blubber depth. Concludes blood chemistries and body condition of newborns were within normal ranges in areas of the stable and declining Steller sea lion populations.

Cates, M. B. and J. P. Schroeder. 1986. The Nutrition of Acclimated vs. Newly Captured *Tursiops truncatus*. *Aquatic Mammals* **12**: 17-20.

Cates, M. B., L. Kaufman, J. H. Grabau, J. M. Pletcher, and J. P. Schroeder. 1986. Blastomycosis in an Atlantic Bottlenosed Dolphin. *Jour. Am. Vet. Med. Assn.* **189**: 1148-1150.

A lethargic, anorexic dolphin with a cranial abscess appeared to respond to treatment but died after four weeks. Upon necropsy, *Blastomyces dermatitidis* was found in all major organs.

Colgrove, G. S., T. R. Sawa, J. T. Brown, P. F. McDowell, and P. E. Nachtigall. 1975. Necrotic Stomatitis in a Dolphin. *Jour. Wildlife Diseases* **11**: 460-464.

Necrotic stomatitis of undetermined etiology was found in an Atlantic bottlenosed dolphin. The case history, treatment, and hematologic findings are described.

Colgrove, G. S. 1975. A Survey of *Erysipelothrix insidiosa* Agglutinating Antibody Titres in Vaccinated Porpoises. *Jour. Wildlife Diseases* **11** (2): 234-236.

Studies of antibody levels in the blood of porpoises previously vaccinated against the disease.

Colgrove, G. S. and G. Migaki. 1976. Cerebral Abscess Associated with Stranding in a Dolphin. *Jour. Wildlife Diseases* **12**: 271-274.

A captive bottlenosed dolphin, which beached itself in the shallows of its enclosure and later died, was found to have an abscess in the right cerebral hemisphere. Examination of the brain revealed a pyogenic meningoencephalitis.

Colgrove, G. S. 1978. Suspected Transportation-Associated Myopathy in a Dolphin. *Jour. Am. Vet. Med. Assn.* **173** (9): 1121-1123.

Evidence suggesting capture myopathy (CM), a potentially fatal condition associated with capture or transport of wildlife, was found in a Pacific bottlenosed dolphin following a routine transportation procedure. With treatment, the animal recovered. It is speculated that “capture shock” in dolphins may have features in common with CM.

Colgrove, G. S. 1978. Stimulation of Lymphocytes from a Dolphin (*Tursiops truncatus*) by Phytomitogens. *Am. Jour. Vet. Res.* **39**: 141-144.

Dolphin lymphocytes responded (by increased thymidine incorporation) to three Phytomitogens, of which one, concanavalin, consistently produced the highest degree of stimulation. Such stimulation could enhance the dolphin’s immune response.

Dailey, M. D. 1969. *Stictodora ubelakeri*, A New Species of Heterophylid Trematode from the California Sea Lion (*Zalophus californianus*). *Bull. So. Calif Acad. Sci.* **68** (2):82-85.

Describes a new species of parasitic flatworm.

Dailey, M. D. and S. H. Ridgway. 1976. A Trematode from the Round Window of an Atlantic Bottlenosed Dolphin’s Ear. *Jour. Wildlife Diseases*. **12**:45-47.

A fluke was found attached to the round window of a dolphin’s ear. The presence of the fluke could impair hearing.

Dailey, M. D. and W. G. Gilmartin. 1980. Diagnostic Key to the Parasites of Some Marine Mammals. NOSC TD 295, 37 pp.

A key, with illustrations, for identification of parasites of marine mammals studied by the Navy.

DeLong, R. L., W. G. Gilmartin, and J. G. Simpson. 1973. Premature Births in California Sea Lions: Association with High Organochlorine Pollutant Residual Levels. *Science* **181**: 1168-1170.

Organochlorine pesticides and polychlorinated biphenyl residues were two to eight times higher in tissues of premature parturient females and pups than in similar tissues of full-term parturient females and pups collected in 1970.

Diamond, S. S., D. E. Ewing, and G. A. Cadwell. 1979. Fatal Bronchopneumonia and Dermatitis Caused by *Pseudomonas aeruginosa* in an Atlantic Bottlenosed Dolphin. *Jour. Am. Vet. Med. Assn.* **175** (9): 984-987.

A female *Tursiops truncatus* captured off Florida ate well and swam normally but consistently lost weight and developed epidermal necrosis. Nodules developed over entire body surface. *Pseudomas aeruginosa* isolated from lesions suspected as etiologic agent. Researchers theorized animal's weakened condition at time of capture provided opportunistic *P. aeruginosa* a fertile environment to proliferate.

Diamond, S. S., C. P. Raflo, M. H. Beleau, and G. A. Cadwell. 1980. Edema Disease in a California Sea Lion. *Jour. Am. Vet. Med. Assn.* **177** (9):808-810.

Describes features and identifies probable causative organism of edema disease, similar to that occurring in swine, that was diagnosed in a sea lion.

Ewalt, D.R., J.B. Payeur, B.M. Martin, D.R. Cummins and W.G. Miller. 1994. Characteristics of a *Brucella* Species from a Bottlenose Dolphin (*Tursiops truncatus*). *Jour. Veterinary Diagnostic Investigation*. **6**: 448-452.

A culture isolated from an aborted bottlenose dolphin *Tursiops truncatus* fetus was characterized. The protein profiles were markedly different from the protein profiles of reference strains of *Brucella* species. Biochemical and oxidative metabolism pro-files indicated that the isolate belongs in the genus *Brucella*, but the profiles did not match that of any established species or biovars. This isolate may be an atypical strain of a recognized *Brucella* species or a new biovar or a new species of *Brucella*.

Fujioka, R. S., S. B. Greco, M. B. Cates, and J. P. Schroeder. 1988. *Vibrio damsela* from Wounds in Bottlenosed Dolphins (*Tursiops truncatus*). *Dis. Aquat. Orgs*. **4**:1-8.

Different *Vibrio* bacteria were recovered from healthy skin and slow-healing wounds of dolphins and from surrounding sea pen water in Hawaii. *Vibrio damsela* predominated in samples from wounds and is identified as the probable primary bacterium causing wound infections in dolphins.

Geraci, J. R. and S. H. Ridgway. 1991. On Disease Transmission Between Dolphins and Humans. *Marine Mammal Science* **7**:191-194.

The authors review the literature on dolphin disease transmission. From their own experience and from the literature reviewed, they conclude that through close association with dolphins, people are just as safe, and probably more so, than through association with companion animals such as dogs.

Gilmartin, W. G., J. F. Allen, and S. H. Ridgway. 1971. Vaccination of Porpoises (*Tursiops truncatus*) Against *Erysipelothrix rhusiopathiae* Infection. *Jour. Wildlife Diseases* **7**:292-295.

A live product was found to stimulate antibody production better than the killed bacterin. An immunization schedule utilizing an initial exposure to the bacterin with subsequent exposures to the live vaccine product is proposed.

Gilmartin, W. G., R. L. Delong, A. W. Smith, J. C. Sweeney, B. W. DeLappe, R. W. Rise-brough, L. A. Griner, M. D. Dailey, and D. B. Peakall. 1976. Premature Parturition in the California Sea Lion. *Jour. Wildlife Diseases* **12**:104-114.

The data suggested an interrelationship of disease agents and environmental contaminants as the cause of premature parturition.

Gilmartin, W. G., P. M. Vainik, and V. M. Neill. 1979. Salmonellae in Feral Pinnipeds Off the Southern California Coast. *Jour. Wildlife Diseases*. **15**:511-514.

Rectal swabs were collected from 90 northern fur seal and 50 California sea lion pups on San Miguel Island. Three *Salmonella* serotypes were recovered from 33 percent of the fur seals and 40 percent of the sea lions.

Hall, J. D., W. G. Gilmartin, and J. L. Mattsson. 1971. Investigation of a Pacific Pilot Whale Stranding on San Clemente Island. *Jour. Wildlife Diseases* **7**: 324-327.

From a stranding of 28 pilot whales, information was obtained on their bacteriology, reproductive tissue, histopathology, liver mercury, and DDE levels. It was concluded that the stranding was a natural event, not precipitated by any pathological condition

Heath, M., S. Ridgway, M. Malik, J. Thomas and W.G. Miller. 1994. Plasma Catecholamines in Bottlenose Dolphin in Warm and Cool Water. *The Physiologist*. **37**: A59.

Plasma epinephrine (EPI) and plasma norepinephrine (NE) were somewhat lower in dolphins acclimated to 25°C water than those acclimated to 15-20°C water. Dolphins showed less than a 2.5 fold increase in NE when moved from warm (25°C) to cooler (15-20°C) water and these levels returned to baseline within 12 weeks of the move. However, this increase in NE is small when compared to the 6-10 fold increase observed in other mammals during severe cold stress. Further studies are needed to determine if plasma NE may be a potential indicator of the magnitude of thermal stress in dolphins.

Hui, C. A. and S. H. Ridgway. 1978. Survivorship Patterns in Captive Killer Whales (*Orcinus orca*). *Bull. So. Calif. Acad. Sci.* **77**:45-51.

Captive killer whales were found to have an overall mortality rate of 4.7 percent per year, with females having a higher rate (7 percent) than males (2.1 percent), and larger females having a shorter captive life span than smaller females. It is suggested that capture stress may be a significant mortality factor; less stressful capture procedures may increase captive life span.

Jensen, E., W. Van Bonn, and S. Ridgway. 1996. Advances in *Tursiops* Gastoenterology. 1996. American Association of Zoo Veterinarians Conf., Puerto Vallarta, Mexico, Nov. 1996.

A succinct description of contemporary diagnostics and therapeutics in cetacean gastrointestinal disease. Includes description of normal anatomy and motility.

Johnston, D. G. and S. H. Ridgway. 1969. Parasitism in Some Marine Mammals. *Jour. Am. Vet. Med. Assn.* **155** (7):1064-1072.

Case histories of parasitism in porpoises and sea lions.

Kamolnick, T., M. Reddy, C. Curry, R. Tarpley and S. Ridgway. 1993. Induced Lactation and Relactation in *Tursiops truncatus* and Fat Content of Milk Collected with a Dolphin Milking Device. 21st Annual IMATA Conf., Kailua-Kona, HI, Nov. 7-12, p.21.

Milk was collected from two *Tursiops* that were induced to lactate by the presence of orphaned calves; the milk was analyzed for fat content.

Linnehan, R.M., R.W. Ulrich, S.H. Ridgway and J.F. McBain. 1992. Determination of Enrofloxacin Serum Activity and Dosage in Atlantic Bottlenose Dolphins (*Tursiops truncatus*). 23rd Annual Conf. of the International Association for Aquatic Animal Medicine, Hong Kong, May 18-22, 1992. **23**:36.

Eight adult *Tursiops truncatus* were given a single dose of orally administered enrofoxacin dosed at 5 mg/kg body weight. Based upon the observed data, the average half-life of enrofloxacin in the study animals was approximately 7 hours with a range from 3.4 to 11 hours. Absorption was somewhat variable with the point of maximal serum concentration ranging from 2 to 8 hours following a single dose. The variation in absorption can most likely be attributed to individual differences in the storage and digestion of the fish ration containing the drug dose within the compartmentalized cetacean stomach.

Martin, J. H., P. D. Elliott, V. C. Anderlini, D. Girvin, S. A. Jacobs, R. W. Hisebrough, R. L. Delong, and W. G. Gilmartin. 1976. Mercury-Selenium-Bromine Imbalance in Pre-mature Parturient California Sea Lions. In: *Marine Biology*. Springer Verlag Publ., New York, pp. 91-104.

Livers and kidneys from 10 normal parturient and 10 premature parturient mothers and their pups were analyzed for 13 trace and major elements. The data suggested a very strong relationship between Hg, Se, and Br in the normal animals but a Br imbalance, in relation to Se and Hg, in the abnormal mothers and their pups. Details and significance of these and other findings are discussed.

Mattsson, J. L. and R. L. Seeley. 1974. Simple Clinical Temperature Telemetry System for Pinnipeds. *Jour. Wildlife Diseases* **10**:267-271.

A radiotelemetry pill was used to monitor core body temperature of sea lions kept in an enclosure. Mean core temperature was found to be 38.10 C.

Meck, S., E. Jensen, and W. Van Bonn. 1995. Health Risks Associated with Pica: A Craving for and Possible Ingestion of Unnatural Articles. 23rd Annual IMATA Conf., Las Vegas, NV, 1995, p. 23.

Paper discusses the approach to the diagnosis, treatment, and prevention of pica.

Medway, W., J. G. McCormick, S. H. Ridgway, and F. H. Crump. 1970. Effects of Pro-longed Halothane Anesthesia on Some Cetaceans. *Jour. Am. Vet. Med. Assn.* **157** (5):576-582.

After prolonged halothane anesthesia (up to 24 hours) variable histologic changes were found, but were judged not to be significant. Plasma enzyme activities monitored did not indicate significant liver damage.

Migaki, G., R. D. Gunnels, and H. W. Casey. 1978. Pulmonary Cryptococcosis in an Atlantic Bottlenosed Dolphin (*Tursiops truncatus*). *Lab. Animal Science* **28**:603-606.

Pulmonary cryptococcosis was diagnosed in a seven-year-old dolphin that had been in captivity for about four years. This was the first report of this disease in a cetacean.

Miller, R. M. and S. H. Ridgway. 1963. Clinical Experiences with Dolphins and Whales. *Small Animal Clinician* **3** (4):189-193.

Diagnosis and treatment of diseases found in dolphins and whales.

Miller, W.G. 1990. Ocular Photography as a Clinical Diagnostic Tool in Marine Mammal Medicine. 21st Annual Conf. of the International Association for Aquatic Animal Medicine, Vancouver, B.C., May 1990, **21**:147.

Describes techniques for use of high quality medical photographic equipment in assisting in ophthalmic exams of marine mammals, value of photos as a permanent dated record for later detailed analysis, and shortcomings of current equipment in obtaining sharp retinal images.

Miller, W.G. and R.J. Tarpley. 1991. An Investigation of Dolphin (*Tursiops truncatus*) Deaths in East Matagorda Bay, Texas in January 1990. 22nd Annual Conf. of the International Association for Aquatic Animal Medicine, Marineland, FL, May 12-16 1991, **22**:39.

The January 1990 acute dolphin mortality event resulted in the deaths of 24 bottlenose dolphins (*Tursiops truncatus*) within East Matagorda Bay, Texas. The December 1989 severe freeze resulted in devastation of the dolphin's most likely major food source, the striped mullet. The dolphins' emaciated condition, substantial reduction in blubber thickness, lack of food in their stomachs, and the fish freeze-kill and bio-mass data suggest, in addition to any direct effects of the extreme cold, that decimation of the food resource contributed to this event.

Miller, W.G. 1992. An Investigation of Bottlenose Dolphin *Tursiops truncatus* Deaths in East Matagorda Bay, Texas, January 1990. *Fish. Bull.* **90**:791-797.

See Miller and Tarpley, 1991, above.

Miller, W.G. 1994. Diagnosis and Treatment of Uric Acid Renal Stone Disease in *Tursiops truncatus*. 25th Annual Conf. of the International Association for Aquatic Animal Medicine. Vallejo, CA, May 11-14, 1994, **25**:22.

Renal stone disease has been diagnosed with ultrasonography and/or radiology and clinical pathology. Two cases have presented with concomitant glomerulonephritis in addition to renal stone disease, and renal cysts have also been observed. Long-term treatment has consisted primarily of increased fluid intake with allopurinol.

Miller, W.G. 1995. Digital Recording of the Electrocardiogram from Bottlenose Dolphins *Tursiops truncatus*. 26th Annual Conf. of the International Association for Aquatic Animal Medicine. Mystic, CT, May 16-10, 1995, **26**:44.

Electrocardiograms were recorded from bottlenose dolphins using an IBM compatible laptop computer, a preamplifier and a "Smart Heart" 3 lead personal heart rate monitor with Windows software.

Miller, W.G. 1995. First Case Report of *Brucella* Abortion in a Bottlenose Dolphin *Tursiops truncatus*. 26th Annual Conf. of the International Association for Aquatic Animal Medicine, Mystic, CT, May 16-10, 1995, **26**:46.

The death of a *Tursiops truncatus* fetus is attributed to *Brucella*. Microbiology results combined with specific PCR results suggest this is a new species, for which the name *Brucella delphini* is suggested. Our findings, together with others, suggest that dolphin Brucellosis is a naturally occurring disease that could adversely impact reproduction in cetaceans.

Miller, W., W. Van Bonn, E. Jensen, S. Ridgway, M. Nowacki, F. Hall and G. Visvesvara. 1996. First Case Report--Pulmonary Amebiasis in a Bottlenose Dolphin *Tursiops truncatus*. 27th Annual Conf. of the International Association for Aquatic Animal Medicine, Chattanooga, TN, May 11-15, 1996, **27**:93-94.

Describes a case of pulmonary ameba infestation in a bottlenose dolphin. Indirect immunofluorescence assay showed this ameba was antigenically dissimilar to 8 different amebic antisera tested including Vahlkampfia avara. Believed to be the first report of an infection of a dolphin caused by a small free-living ameba.

Myhre, B. A., J. G. Simpson, and S. H. Ridgway. 1971. Blood Groups in the Atlantic Bottle-nosed Porpoise (*Tursiops truncatus*). Soc. Expl. Biol. Med. **137**:404-407.

A study of porpoise blood demonstrated three blood groups. Transfusions must be made with blood matching that of the recipient.

Myrick, A. C. Jr., W. E. Stuntz, S. H. Ridgway, and D. K. Odell. 1987. Hypocalcemia in Spotted Dolphins (*Stenella attenuata*) Chased and Captured by a Purse Seiner in the Eastern Tropical Pacific. (Abs.). Seventh Biennial Conf. on the Biology of Marine Mammals, Society of Marine Mammalogy, Miami, FL., p. 49.

Blood samples from dolphins that had been chased in tuna sets were tested for calcium level. These levels were found to be low compared to previously published values on healthy dolphins. It is possible that the observed hypocalcemia was due to the stress of chase and capture.

Nachtigall, P. E., J. L. Pawloski, J. P. Schroeder, and S. Sinclair. 1990. Successful Maintenance and Research with a Formerly Stranded Risso's Dolphin (*Grampus griseus*). *Aquatic Mammals* **16** (1):8-13.

The rehabilitation of a stranded *Grampus* is described. Values for blood parameters are listed. Subsequent research with the animal is described.

Palmer, C., J. P. Schroeder, R. S. Fujioka, and J. Douglas. 1991. Staphylococcus aureus Infection in Newly Captured Pacific Bottlenosed Dolphins. *Jour. of Zoo and Wildlife Medicine* **22** (3):330-338.

The diagnostic tests employed to identify the origin of Staph organisms isolated from dolphins captured around the Hawaiian Islands are described.

Pawloski, J. L. and P. E. Nachtigall. 1988. Simultaneous Measurement of Oral and Rectal Temperatures in a Nonrestrained Atlantic Bottlenosed Dolphin. (Abs.) Annual IMATA Conf., San Antonio, TX.

Utilizing a specialized mouthpiece, safe and accurate oral temperatures were measured in an Atlantic bottlenosed dolphin concurrently while measuring the animal's rectal body temperature. These data were collected on a routine basis with an animal trained specifically for this task.

Payeur, J.B. D.R. Ewalt, B.M. Martin, D.R. Cummins and W.G. Miller. 1992. Characteristics of a *Brucella* Species from a Bottlenose Dolphin (*Tursiops truncatus*). 35th Annual Meeting of the American Association of Veterinary Laboratory Diagnosticians, Louisville, KY, Nov. 1992, p. 43.

A culture isolated from an aborted bottlenose dolphin fetus was characterized. The protein profiles were markedly different from the protein profiles of reference strains of *Brucella* species. This isolate may be an atypical strain of a recognized species or a new biovar or new species of *Brucella*.

Reddy, M.L., P. Kamolnick, D. Skaar, C. Curry and S.H. Ridgway. 1991. Bottlenose Dolphins: Energy Consumption During Pregnancy, Lactation, and Growth. 19th Annual IMATA Conf., Vallejo, CA, Nov. 4-8, 1991, pp. 30-37.

Energy consumption measured in kilocalories was monitored during pregnancy, lactation and early growth.

Reddy, M, T. Kamolnick, C. Curry, D. Skaar and S. Ridgway. 1992. Energy Requirements for the Bottlenose Dolphin, *Tursiops truncatus*, in Relation to Sex, Age and Reproductive Status. 20th Annual IMATA Conf., Grand Bahamas, Nov. 1-6, 1992, p. 23.

Calorie consumption was tracked for 16 *Tursiops truncatus* at different stages of growth and reproductive status to determine their caloric requirements.

Reddy, M.L. and S. Ridgway. 1993. Organochlorines in Milk from Varied Stages of Lactation of Trained *Tursiops truncatus*. Tenth Biennial Conf. on the Biology of Marine Mammals, Galveston, TX, Nov. 11-15, 1993, p. 90.

Organochlorine residues were measured in milk from various stages of lactation of five healthy trained *Tursiops truncatus*.

Reddy, M., S. Ridgway and W. Van Bonn. 1993. Factors to Consider When Determining Diets for Pregnant and Lactating Bottlenose Dolphins. 21st Annual IMATA Conf., Kailua-Kona, HI, Nov. 7-12, 1993, p. 21.

Presentation discusses ration formulation during gestation and lactation for dolphins, especially in regard to calcium levels in various fish species.

Reddy, M. and S. Ridgway. 1994. What the Heck are Organochlorines and What Are They Doing in My Dolphin's Milk? 22nd Annual IMATA Conf., Tacoma, WA, Nov. 6-11, 1994, p. 16.

Ridgway, S. H. 1967. Anesthetization of Porpoises for Major Surgery. *Science* **158** (3800): 510-512.

Account of a technique for achieving deep anesthesia in porpoises. Major surgery (ovario-hysterectomy) has been performed with complete recovery.

Ridgway, S. H. and J. G. Simpson. 1967. Anesthesia and Restraint for the California Sea Lion (*Zalophus californianus*). *Jour. Am. Vet. Med. Assn.* **155** (7):1059-1063.

Describes a technique for anesthetizing sea lions, and the configuration of a unique restraining cage which enables the animal to be examined, treated, or anesthetized without harm to either the sea lion or the handlers.

Ridgway, S. H. 1968. The Bottlenosed Dolphin in Biomedical Research. In: *Methods in Animal Experimentation*, W.I. Gay (ed.). Academic Press, San Diego, CA. **3**:387-446.

A broad account of the characteristics and behavior of the bottlenosed dolphin as they relate to health care and biomedical research.

Ridgway, S. H. and J. G. McCormick. 1971. Anesthesia of the Porpoise. In: *Textbook of Veterinary Anesthesia*, L. R. Soma (ed.). The Williams and Wilkins Co., Baltimore, MD, pp. 394-403.

Discusses special considerations on anesthetizing cetaceans, reviews history of attempts at anesthetization and describes a successful technique utilizing halothane as the anesthetic.

Ridgway, S. H. and M. D. Dailey. 1972. Cerebral and Cerebellar Involvement of Trematode Parasites in Dolphins and Their Possible Role in Stranding. *Jour. Wildlife Diseases* **8**:33-43.

Trematode parasites found in the brains of stranded porpoises may offer an explanation for some cetacean strandings.

Ridgway, S. H., J. R. Geraci, and W. Medway. 1975. Diseases of Pinnipeds. *Rapp. P.-v. Reun. Cons. Int. Explor. Mer*. **196**:327-337.

The major disease conditions encountered in pinnipeds are described.

Ridgway, S. H., R. F. Green, and J. C. Sweeney. 1975. Mandibular Anesthesia and Tooth Extraction in the Bottlenosed Dolphin. *Jour. Wildlife Diseases* **11**:415--418.

Describes a technique for anesthetizing the lower jaw for tooth extraction.

Ridgway, S. H. 1977. Brain Abscesses, Flukes, and Strandings. (Abs.) In: *Biology of Marine Mammals: Insights Through Strandings*, J. B. Geraci and D. J. St. Aubin (eds.). Report prepared for Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-293-890, pp. 83-84.

Argues that brain abscesses resulting from trematode infestation, which have been found in a number of stranded dolphins, contribute to stranding.

Ridgway, S. H. 1979. Reported Causes of Death of Captive Killer Whales (*Orcinus orca*). *Jour. Wildlife Diseases* **15**:99-104.

A variety of diseases and other pathologic conditions were found responsible for deaths of captive killer whales. Captive females appeared to have a higher mortality rate than males. Growth rates for whales that died were greater than for those that survived.

Ridgway, S. H. 1983. Dolphin Hearing and Sound Production in Health and Illness. In: *Hearing and Other Senses: Presentations in Honor of E. G. Wever*, R. R. Fay and G. Gurevich (eds.). Amphora Press, Groton, CN, pp. 247-296.

Review of findings on dolphin hearing, with accounts of modern anatomic and physiologic work on the ear; the brain, evoked potentials, and audition; and evidence that sound production can be used to assess dolphin health and mood.

Ridgway, S.H. 1993. Dolphins in the Care of Humans: A Look Toward the Future. International Marine Biological Research Institute Reports. **4**:19-32.

This paper reviews past studies by the author on dolphin care. Current studies are described, and suggestions are made for future scientific endeavors concerning animal care.

Ridgway, S.H. 1993. Delphinoid Cetaceans in Human Care: Toward the 21st Century. Keynote address, 21st Annual IMATA Conf., Kailua-Kona, HI, Nov. 7-12, 1993.

Delphinoid cetaceans (white whales and dolphins) kept in North America are discussed. Suggestions are outlined for future research needs concerning care of these animals.

Ridgway, S.H. and M.L. Reddy. 1995. Conservation: Marine Mammal Health. Proceedings of the Strategic Environmental Research and Development Program, Washington, D.C., April 12-14, 1995 .

A presentation made in Washington, D.C. outlining the use of the Navy's marine mammals to measure baseline levels of organochlorines in the blubber, blood, and milk of healthy reproducing animals for use in conservation strategies in ocean habitats.

Ridgway, S. and M. Reddy. 1995. Residue Levels of Several Organochlorines in *Tursiops truncatus* Milk Collected at Varied Stages of Lactation. *Marine Pollution Bulletin*. **30**:609-614.

The concentrations of several organochlorines (PCB, DDT, dieldrin, heptachlor) were measured in serial samples of milk collected from healthy reproducing *Tursiops truncatus*. This is the first report of results from analyses of contaminant concentrations of multiple specimens from the same individual.

Romano, T., D.L. Felten, S.H. Ridgway and V. Quaranta. 1995. Cetaceans: Immune Function and Defense Mechanisms. 26th Annual Conf. of the International Association for Aquatic Animal Medicine, Mystic, CT, May 16-10, 1995, **26**:68.

Discusses features of the cetacean immune system with special reference to cetacean health considerations.

Romano, T.A., S.H. Ridgway, D.L. Felten, and V. Quaranta. 1996. The Development of Molecular Markers for Investigation of the Cetacean Immune System. 27th Annual Conf. of the International Association for Aquatic Animal Medicine, Chattanooga, TN, May 11-15, 1996, **27**:5.

The development and sequence of a beluga CD4-specific marker.

Schroeder, J. P., J. G. Wallace, M. B. Greco, and P. W. B. Moore. 1985. An Infection by *Vibrio alginolyticus* in an Atlantic Bottlenosed Dolphin Housed in an Open Ocean Pen. *Jour. Wildlife Diseases* **21**:437-438.

Describes the lesions on a dolphin that had a history of skin problems, the culture techniques used to identify the pathogen, and the successful therapy following tests to determine sensitivity of the *Vibrio* organisms to a variety of antibiotics. Also discusses the susceptibility of humans to infection by *Vibrio* ssp.

Schroeder, J. P. 1987. Marine Mammal Health Management Based on Immune System Response to Stress and Infectious Disease. (Abs.) Seventh Biennial Conf. on the Biology of Marine Mammals. Society of Marine Mammalogy, Miami, FL., p. 61.

Information on health management of marine mammals based on research at NOSC is presented.

Schroeder, J. P., D. M. Fry, and N. A. Vedros. 1989. Assessment and Management of Response to Stressors of Oil Contamination of Sea Otters (*Enhydra lutris*). (Abs.) Eighth Biennial Conf. on the Biology of Marine Mammals. Society of Marine Mammalogy, Pacific Grove, CA., p. 61.

The immune system response of sea otters to the Exxon Valdez oil spill and identification of acute phase response parameters are linked to management and rehabilitation techniques.

Shinder, D. M. 1983. Separation and Removal of Marine Mammals for Medical Examination. Annual IMATA Conf., Apple Valley, MN, pp. 93-102.

This paper describes four methods for removing dolphins from the water for physical examination. The resources needed and procedures used are presented for crowding, stranding, beaching, and tail presentation.

Simpson, J. G. and W. G. Gilmartin. 1970. An Investigation of Elephant Seal and Sea Lion Mortality on San Miguel Island. *Bioscience*, March 1, 1970, p. 289.

At the request of state and federal authorities following the Santa Barbara oil spill, an investigation was made to determine if oil washing up on San Miguel Island had affected any of the seals and sea lions there. No evidence was found of illness or mortality attributable to the oil.

Smith, A. W., C. M. Prato; W. G. Gilmartin, R. J. Brown, and M. C. Keyes. 1974. A Preliminary Report on Potentially Pathogenic Microbiological Agents Recently Isolated from Pinnipeds. *Jour. Wildlife Diseases* **10**:54-59.

Leptospira may be one cause of reproductive failure (abortion) in California sea lions and fur seals. Certain virus isolations from sea lions and fur seals appeared indistinguishable from vesicular exanthoma, a swine virus, which is known to cause abortion in swine. Pinnipeds may constitute a reservoir for virus diseases that infect terrestrial mammals.

Smith, A. W., N. A. Vedros, T. G. Akers, and W. G. Gilmartin. 1978. Hazards of Disease Transfer from Marine Mammals to Land Animals: Review and Recent Findings. *Jour. Am. Vet. Med. Assn.* **173**:1131-1133.

Certain disease agents, bacterial and viral, are widespread in a variety of marine mammals, and some are transmissible to a number of terrestrial mammal species.

Smith, A. W. and D. E. Skilling. 1979. Viruses and Virus Diseases of Marine Mammals. *Jour. Am. Vet. Med. Assn.* **175**:918-920.

Presents information on the kinds of viruses that have been isolated from pinnipeds and cetaceans, and shows, where possible, the relationship of these agents to specific diseases.

Smith, A. W., D. E. Skilling, and S. H. Ridgway. 1983. Calicivirus-induced Vesicular Disease in Cetaceans and Probable Interspecies Transmission. *Jour. Am. Vet. Med. Assn.* **183**:1223-1225.

A new calicivirus serotype, isolated from a dolphin, was apparently transmitted from the dolphin to a sea lion and from the sea lion to another dolphin.

Smith, A. W., D. E. Skilling, and S. H. Ridgway. 1983. Regression of Cetacean Tattoo Lesions Concurrent with Conversion of Precipitin Antibody Against a Poxvirus. *Jour. Am. Vet. Med. Assn.* **183**:1219-1222.

Tattoo lesions linked to cetacean poxvirus in bottlenosed dolphins regressed without treatment. Regression was concurrent with antibody conversion.

Stevens, M.G. and W.G. Miller. 1995. Antigenic Characterization of a *Brucella* Species Isolated from a Bottlenose Dolphin. 76th Conf. of Research Workers in Animal Diseases, Chicago, IL, Nov. 1995.

The antigens of *Brucella delphini* (proposed name for this bacterium) were characterized. Results indicate that *B. delphini* contain a <20kDa antigenic protein which is shared with other smooth and rough strains of *Brucella*. This protein may be useful in developing a diagnostic antibody test for determining the prevalence of antibody to *Brucella* in dolphins and other marine mammals.

Suer, L. D., N. A. Vedros, J. P. Schroeder, and J. L. Dunn. 1988. *Erysipelothrix rhusiopathiae*. II. Enzyme Immunoassay of Sera from Wild and Captive Marine Mammals. *Dis. Aquat. Orgs.* **5**: 7-13.

An enzyme immunoassay was developed and used on sera from marine mammals. Wild bottlenosed dolphins had lower antibody levels than captive, vaccinated cetaceans. Antibody levels in wild and captive pinnipeds varied. Possible explanations for erratic and low antibody levels observed are discussed.

Sweeney, J. C. 1974. Transfusion of Homologous and Heterologous Red Blood Cells (Washed And Unwashed) in the California Sea Lion. Annual American Association of Zoo Veterinarians Conf., pp. 131-135.

Red blood cells tagged with 51cr were used to compare the longevity of homologous and heterologous (sheep) transfused cells. The sheep cells were quickly removed from circulation.

Sweeney, J. C. 1974. Common Diseases of Pinnipeds. *Jour. Am. Vet. Med. Assn.* **165**(9):805-810.

Discusses the various diseases found in seals, sea lions, and walruses.

Sweeney, J. C. 1974. Procedures for Clinical Management of Pinnipeds. *Jour. Am Vet. Med. Assn.* **165**(9):811-814.

Describes clinical approach to diagnoses, treatment techniques, surgical procedures, dietary problems, and physical injuries.

Sweeney, J. C. and W. G. Gilmartin. 1974. Survey of Diseases in Free-Living California Sea Lions. *Jour. Wildlife Diseases* **10**:370-376.

Presents data on 51 California sea lions that stranded on southern California beaches and were examined by necropsy. Includes comments on the diagnosis and treatment of the more commonly found diseases.

Sweeney, J. C. and S. H. Ridgway. 1975. Procedures for the Clinical Management of Small Cetaceans. *Jour. Am. Vet. Med. Assn.* **167**:540-545.

Methods for the treatment of disease and injury in small cetaceans.

Sweeney, J. C. and S. H. Ridgway. 1975. Common Diseases of Small Cetaceans. *Jour. Am. Vet. Assn.* **167**:533-540.

Brief descriptions of commonly encountered disease conditions.

Sweeney, J. C., G. Migaki, P. M. Vainik, and R. H. Conklin. 1976. Systemic Mycoses in Marine Mammals. *Jour. Am Vet. Med. Assn.* **169** (9):946-948. Thirty-four cases of systemic mycosis were represented by nine genera of fungi. All were characterized by pulmonary involvement.

Sweeney, J. C. 1977. Intratracheal Injection of Antibiotics in the California Sea Lion (*Zalophus californianus*) and bottlenosed dolphin (*Tursiops truncatus*). *Jour. Wildlife Diseases* **13**:49-54.

Gentamycin and cephaloridine were administered by intratracheal injections, and uptake and clearance in the blood were monitored. In all cases, absorption through the respiratory mucosa resulted in blood levels approaching therapeutic concentrations despite low dosages.

Sweeney, J. C. 1977. Difficult Births and Neonatal Health Problems in Small Cetaceans. In: *Breeding Dolphins: Present Status. Suggestions for the Future*, S. H. Ridgway and K. Benirschke (eds.). A report to the Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-273 673, pp. 278-287.

Analysis of records of stillbirths, difficulties in labor (dystocias), and neonatal health problems and mortalities, with conclusions and recommendations.

Sweeney, J. C. 1977. Diagnosis of Pregnancy in Small Cetaceans with Doppler Sonography and Other Techniques. In: *Breeding Dolphins: Present Status. Suggestions for the Future*, S. H. Ridgway and K. Benirschke (eds.). A report to the Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-273 673, pp. 211-216.

Discusses electronic devices and various techniques by which pregnancy and fetal viability can be determined.

Townsend, F.I. and S.H. Ridgway. 1995. Kidney Stones in Atlantic Bottlenose Dolphins (*Tursiops truncatus*): Composition, Diagnosis and Therapeutic Strategies. 26th Annual Conf. of the International Association for Aquatic Animal Medicine, Mystic, CT, May 16-10, 1995, **26**:2.

Ultrasonography was used to diagnose renal calculi in a *Tursiops truncatus*. This outlines suggested therapies and strategies for treating kidney stones in *Tursiops*.

Van Bonn, W. 1995. Mission Accomplishment: Current Status of Clinical Veterinary Services, U.S. Navy Marine Mammal Program. 26th Annual Conf. of the Inter-national Association for Aquatic Animal Medicine, Mystic, CT, May 16-10, 1995, **26**:80.

Paper describes the status of the Navy's marine mammal population and preventive medicine program.

Van Bonn, W. 1995. Captive Cetaceans. *Jour. Am. Vet. Med. Assn.* **206** (2):155-156. A letter to the editors regarding captive cetaceans and military working animals.

Van Bonn, W., S. Ridgway, and B. Williams. 1995. Chronic Refractory Emesis Associated with a Colonic Lesion in a California Sea Lion *Zalophus californianus*. *Jour. Zoo. and Wildlife Medicine*. **26** (2):286-292.

A case report describing an unusual presentation of large bowel disease in a California sea lion and medical treatments attempted.

Van Dyke, D. 1972. Contingency Rations for California Sea Lions. NUC TP 317, 7 pp. Describes the formulation and testing of a prepared ration that may be fed exclusively for at least 4 weeks.

Van Dyke, D. and S. H. Ridgway. 1977. Diets for Marine Mammals. In: *Handbook of Nutrition and Food*, M. Rechcigl (ed.). CRC Press, Cleveland, OH, pp. 595-598.

Diets and caloric intakes of various marine mammals are described.

Williams, T.M., S.F. Shippee, and M.J. Rothe. 1996. Strategies for Reducing Foraging Costs in Dolphins. In: *Aquatic Predators*, S. Greenstreet and M.L. Tasker (eds.) Blackwell Science Ltd., London, pp. 4--9.

Discusses a study of energetic costs associated with, and restricting time for, foraging. This effort addresses energy costs of locomotion, thermoregulation and digestion for bottlenose dolphins (*Tursiops truncatus*) and concludes their behaviors to reduce these costs benefit foraging animals by conserving limited oxygen reserves during a dive.

5. BREEDING

Brook, F. D., Chow, T. Lam, and J. P. Schroeder. 1991. Ultrasound Imaging of the Male Reproductive Tract of the Pacific Bottlenosed Dolphin (*Tursiops truncatus*) and its Significance in Breeding Management. (Abs.) *Brit. Jour. Radiology* **64**: 654.

New findings of a longitudinal study of dolphin testis size correlated with serum testosterone levels and a description of anatomical features visualized by ultrasonography are presented basis for these differences.

Hill, H. and W. G. Gilmartin. 1977. Collection and Storage of Semen from Dolphins. In: *Breeding Dolphins: Present Status. Suggestions for the Future*, S. H. Ridgway and K. Benirschke (eds). A report to the Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-273 673, pp. 205-210.

Discusses relevant considerations and provides details of techniques used.

Hui, C. A. 1977. Growth and Physical Indices of Maturity in the Common Dolphin (*Delphinus delphis*). In: *Breeding Dolphins: Present Status. Suggestions for the Future*, S. H. Ridgway and K. Benirschke (eds.). A report to the Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-273 673, pp. 231-260.

Describes growth patterns (as known) in delphinids and discusses the various physical features that provide indication of age or sexual maturity. A "Robustness Quotient" appears to provide a good indicator for female sexual maturity, while a "Flipper Index" (derived from radiographs showing a degree of epiphyseal fusion) provides an estimate of gonad development in males.

Judd, H. L. and S. H. Ridgway. 1977. Twenty-four Hour Patterns of Circulating Androgens and Cortisol in Male Dolphins. In: *Breeding Dolphins: Present Status. Suggestions for the Future*, S. H. Ridgway and K. Benirschke (eds.). A report to the Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-273 673, pp. 269-277.

Ultradian and diurnal fluctuations of circulating testosterone were not found in two male *Tursiops* sampled every 20 minutes for 24 hours.

Keller, K. V. 1987. Training Atlantic Bottlenosed Dolphins (*Tursiops truncatus*) for Artificial Insemination. Proceedings, International Marine Animals Trainers Association Conference, Vancouver B. C., Canada, Oct. 27-31, 1986, pp. 22-24.

Describes the training of behaviors supporting research in breeding bottlenosed dolphins in captivity.

Kirby, V. L. and S. H. Ridgway. 1984. Hormonal Evidence for Spontaneous Ovulation of Captive Dolphins (*Tursiops truncatus* and *Delphinus delphis*). *Rep. Int. Whal. Comm.* Special Issue **6**:459--464.

It was concluded that captive females of both species can exhibit spontaneous ovulation; can be anestrous for at least a one-year period; and can be polyestrous, with an observed maximum of 3 cycles/year for *Tursiops* and 7 cycles/year for *Delphinus*.

Ridgway, S. H. and R. F. Green. 1967. Evidence for a Sexual Rhythm in Male Porpoises. *Norwegian Whaling Gazette* **1**:1-8.

Describes seasonal changes in the reproductive organs of two species of porpoises.

Ridgway, S. H., K. S. Norris, and L. H. Cornell. 1989. Some Considerations for Those Wishing to Propagate Platanistoid Dolphins. In: *Biology and Conservation of River Dolphins*, W.F. Perrin, R.L. Brownell, Jr., K. Zhou, and J. Liu (eds.). IUCN Species Survival Commission Occasional Paper No. 3, pp. 159-167.

Considers aspects of successful breeding programs with other dolphins (particularly *Tursiops*) and recommends approaches that might be relevant to propagation of endangered river dolphins.

Ridgway, S.H. 1995. The Tides of Change: Conservation of Marine Mammals. In: *Conservation of Endangered Species in Captivity: An Interdisciplinary Approach,* E.F. Gibbons, B.S. Durrant and J. Demarest (eds.). State University of New York Press, Albany, pp. 407-424.

An overview of marine mammals—their current status in the wild, reproductive histories in marine mammal facilities, and breeding strategies for the future.

Schroeder, J. P. and K. V. Keller. 1989. Seasonality of Serum Testosterone Levels and Sperm Density in *Tursiops truncatus*. *Jour. Exper. Zool.* **249**:316-321.

Blood and semen were collected at regular intervals over 28 months. Maximum sperm count and density and minimum serum testosterone levels coincided with the period of peak breeding activity.

Schroeder, J. P. 1990. Breeding Bottlenosed Dolphins in Captivity. In: *The Bottlenosed Dolphin*, J. S. Leatherwood and R. R. Reeves (eds.). Academic Press, San Diego, CA, pp. 435-446.

A review of the captive breeding program at NOSC is presented. Reproductive physiology and the husbandry and management of a breeding herd of captive Atlantic bottlenosed dolphins are discussed.

Schroeder. J. P. 1990. Reproductive Aspects of Marine Mammals. In: *Handbook of Marine Mammal Medicine: Health, Disease, and Rehabilitation*, L. A. Dierauf (ed.). CRC Press, Cleveland, OH, pp. 353-369.

A review of the reproductive natural history, biology and physiology of cetaceans and pinnipeds is presented, including veterinary science and medical techniques.

Schroeder, J. P. and K. V. Keller. 1990. Artificial Insemination of Bottlenosed Dolphins. In: *The Bottlenosed Dolphin*, J. S. Leatherwood and R. R. Reeves (eds.). Academic Press, San Diego, CA, pp. 447-460.

The development of semen collection, cryopreservation, and artificial insemination techniques for dolphins is reported.

Schroeder, J. P. 1991. Reproduction in Marine Mammals. In: *Captive Conservation of Endangered Species*, J. Demarest, B. Durrant, and G. Gibbons (eds.). State University of New York Press, Albany, NY.

A review of reproductive biology of marine mammals with special emphasis on the applicability of new techniques to the most endangered species, the baiji.

Schroeder, J. P. 1991. Marine Mammal Reproduction. In: *Zoo and Wild Animal Medicine*, Vol. III, M. Fowler (ed.). Saunders Press, Philadelphia, PA.

A discussion of current veterinary medical and surgical techniques used in the care and management of captive marine mammals.

Schroeder, J.P. 1991. Ultrasound Imaging of the Male Reproductive Tract of the Pacific Bottlenose Dolphin and Its Significance in Breeding Management. 22nd Annual Meeting of the British Medical Ultrasound Society, London, Dec. 7, 1990. Pub. in *British Jour. Radiology*. July 1991.

Wood, F.G. 1977. Births of Porpoises at Marineland, Florida. 1939-1969, and Comments on Problems in Captive Breeding of Small Cetacea. In: *Breeding Dolphins: Present Status and Suggestions for the Future*, S.H. Ridgway and K. Benirschke (eds.). A report to the Marine Mammal Commission. Nat'l Tech. Info. Serv. PB-273 673, pp. 47-60.

Discusses behavioral factors, births to captive-born females, time of year births occurred, stillbirths, and infant mortalities, with relevant tables, including a listing of 40 births with dates, sex of calf, name of dam, place of conception (ocean or tank), parturition time, and additional details.

6. BEHAVIOR/PSYCHOPHYSICS

Beach, F. A., III and R. L. Pepper. 1971. Marine Mammal Training Procedures: The Effects of Scheduled Reinforcement in the Dolphin (*Tursiops truncatus*). NUC TP 214, 72 pp.

The strength of a behavior conditioned on a one-reward-for-one-response basis was compared with that conditioned on several types of schedules in which more than one response was required for a reward. All schedules provided good control, but a variable-ratio schedule produced a larger amount of work over a longer period and at a greater rate for the same amount of reward.

Beach, F. A., III and L. M. Herman. 1972. Preliminary Studies of Auditory Problem Solving and Intertask Transfer by the Bottlenosed Dolphin. *Psych. Rec.* **22**: 49-62.

Describes successive reversal training and discrimination learning set experiments with two bottlenosed dolphins.

Beach, F. A., III and R. L. Pepper. 1972. Operant Responding in the Bottlenosed Dolphin (*Tursiops truncatus*). *Jour. Exper. Anal. Behavior* **17** (2): 159-160.

Describes experiments to determine the relative efficacies of various food-reinforcement schedules in a paddle-press task.

Beach, F. A., III, R. L. Pepper, J. V. Simmons, Jr., P. F. Nachtigall, and P. A. Siri. 1974. Spatial Habit Reversal in Two Species of Marine Mammals. *Psych. Rec.* **24**: 385-391.

Two California sea lions and one Atlantic bottlenosed dolphin were tested over 19 reversals of a spatial problem. All performed well.

Chaplin, M., T. Kamolnick, M. Todd, and W. Van Bonn. 1996. Conditioning *Tursiops Truncatus* for Nasal Passage Endoscopy. (Abs.) 24th Annual IMATA Conf., Gold Coast, Australia, Nov. 3-8.

Details training of two *Tursiops* to accept a flexible fiberoptic endoscope into the blowhole to view the internal upper respiratory anatomy (epiglottal, nasal cavity and peri-blowhole structure) during echolocation to examine the role this structure may play in sound production.

Chun, N. K. W. 1978. Aerial Visual Shape Discrimination and Matching-to-Sample Problem-Solving Ability of an Atlantic Bottlenosed Dolphin. NOSC TR 236, 24 pp.

Two-dimensional geometric shapes of various configurations were presented. Large differences in perimeter lengths between any two shapes generally resulted in better performance. Other form parameters may be involved in the discriminative process. Evidence indicated problem-specific rather than conceptual learning.

Cramer, A. and A. Pitts. 1996. The Use of Commercially Available Software Programs in Marine Mammal Management. (Abs.) 24th Annual IMATA Conf., Gold Coast, Australia, Nov. 3-8.

Discusses the use of commercial data management applications for behavioral and dietary data collection in management of marine mammals, which allowed decisions regarding the animals' health and training.

Cummings, W. C., P. O. Thompson, and J. F. Fish. 1974. Behavior of Southern Right Whales: R/V Hero Cruise 72-3. *Antarctic Jour. U.S.* **9** (2):33-38.

Describes behaviors and underwater sounds of right whales in Golfo San Jose, Argentina. No decided change in behavior was elicited by playback of southern right whale sounds or the sounds of northeast Pacific killer whales.

Flanigan, W. F., Jr. 1974. Nocturnal Behavior of Captive Small Cetaceans. 1. The Bottlenosed Porpoise (*Tursiops truncatus*). (Abs.) *Sleep Research*. **3**: 84.

Observed behavior consisted of periods of unambiguous waking, stereotypic circular swimming with brief (20-30 seconds) eye closure and other indications of sleep, and quiescent "hanging" behavior with similar indications of sleep.

Flanigan, W. F., Jr. 1974. Nocturnal Behavior of Captive Small Cetaceans. 2. The Beluga Whale (*Delphinapterus leucas*). (Abs.) *Sleep Research* **3**: 85.

Observed behavior consisted of active waking, quiet waking, and stereotypic circular swimming. The last does not meet all the criteria used to define sleep in terrestrial animals but probably reflects adaptations to an aquatic environment.

Gisiner, R. C. and R. J. Schusterman. 1991. California Sea Lion Pups Play an Active Role in Reunions With Their Mothers. *Animal Behavior* **41** (2): 364-366.

Presents and discusses data showing that pups less than one week old respond only to their mothers' call and as they grow older, play an increasingly active role in reunions with others which have spent time away from the pup.

Gisiner, R. C. and R. J. Schusterman. 1991. Complex Conditional Relationships Learned by a Language-Trained Sea Lion (Abs.) 32nd Annual Meeting of the Psychonomic Society, San Francisco, November 1991. *Bulletin of the Psychonomic Society* **29** (6):486.

A sea lion was trained to respond appropriately when 2 to 7 signs were presented. If missing, added, or disoriented signs were presented, the animal demonstrated that she had learned more than the specifically trained paired-associate relationships between signs and referents.

Gonzales, B.A., R.E. Cartee and S.H. Ridgway. 1993. Conditioning a California Sea Lion (*Zalophus californianus*) for Voluntary Ultrasound as a Husbandry Tool. 21st Annual IMATA Conf., Kailua-Kona, HI, Nov. 7-12.

Sea lions were trained to present different body parts for ultrasound evaluation. Methods of training were discussed.

Hall, R.W. and R. Stitt. 1996. Conditioning Dolphins for Temporary Holding Pools. 24th Annual IMATA Conf., Gold Coast, Australia, Nov. 3-8.

Navy dolphins had been temporarily maintained in "above ground" holding pools for medical procedures, observation, environmental emergencies and at-sea shipboard deployments. Explains the behavioral conditioning process for various pool configurations, emphasizing acclimation, medical and beaching behaviors.

Haun, J. E. 1977. Trainer and Trainer Transfer of Marine Mammals Utilizing Collateral Behaviors. In: Proceedings, IMATA Conference, D. I. McSheehy and G. B. Peiterson (eds.). New England Aquarium, Boston, pp. 65-79.

Discusses the classification and quantification of innovative or animal-initiated behaviors that occur in performance of a conditioned chain of behaviors and describes how such collateral behaviors pertain to training and can be used to facilitate transfer of an animal from one trainer to another.

Hui, C. A. 1989. Surfacing Behavior and Ventilation in Free-ranging Dolphins. *Jour. Mammal.* **70** (4):833-835.

Ventilation intervals are estimated from video images of *Delphinus* and *Stenella* swimming near boats. Results used to support speculations on behavioral and bioenergetic consequences of dolphins surfacing to breathe at different swimming speeds.

Irvine, B. 1971 (1972). Behavior Changes in Dolphins in a Strange Environment. *Quart. Jour. Florida Acad. Sci.* **34** (3):206-212.

Sluggish and unresponsive behavior was observed in dolphins when they were first moved from tanks to lagoon pens. Similar behavior was noted in animals that escaped from their pens or wandered away from the trainer during early training. It is suggested that this was a response to a strange environment.

Kamolnick, T., M. L. Reddy, D. Miller, C. Curry and S. Ridgway. 1992. Conditioning a Bottlenose Dolphin (*Tursiops truncatus*) for Milk Collection. 20th Annual IMATA Conf., Grand Bahamas, Nov. 1-6, p. 24.

Two lactating *Tursiops truncatus* was conditioned to allow for the collection of milk samples. Training methods are outlined.

Kamolnick, T., M. Reddy, D. Miller, C. Curry and S. Ridgway. 1994. Conditioning a Bottlenose Dolphin (*Tursiops truncatus*) for Milk Collection. *Marine Mammals*: *Public Display and Research*. **1** (1): 22-25.

Two lactating *Tursiops truncatus* were conditioned to allow for the collection of milk samples. Training methods are outlined and collection devices are reviewed.

Kamolnick, T., M. Todd, M. Beeler and J. Ross. 1996. Conditioning Strategy for Open Water Research. (Abs.) 24th Annual IMATA Conf., Gold Coast, Australia, Nov. 3-8.

Reports on follow-on to an earlier study in which white whales (*Delphinapterus leucas*) were conditioned for hearing studies at 100 meters. This extended that testing to 200 and 300 meters. Discusses the development of conditioning strategies employed in the study in the unpredictable environment of the open sea.

Leatherwood, J. S. 1974. A Note on Gray Whale Behavioral Interactions with Other Marine Mammals. *Mar. Fish. Rev.* **36** (4):50-51.

Porpoises of a number of species were observed riding the pressure waves of the whales. Whales were also observed riding large swells in a manner similar to that seen in smaller cetaceans.

Leatherwood, J. S. 1975. Some Observations of Feeding Behavior of Bottlenosed Dolphins (*Tursiops truncatus*) in the Northern Gulf of Mexico and (*Tursiops cf T. gilli*) off Southern California, Baja California, and Nayarit, Mexico. *Mar. Fish. Rev.* **37** (9): 10-16.

Seven distinct feeding behaviors, in which a variety of prey species are taken by various means, are identified and discussed.

Leatherwood, J. S. 1977. Some Preliminary Impressions on the Numbers and Social Behavior of Free-swimming Bottlenosed Dolphin Calves (*Tursiops truncatus*) in the Northern Gulf of Mexico. In: *Breeding Dolphins: Present Status. Suggestions for the Future*, S. H. Ridgway and K. Benirschke (eds.). A report to the Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-273 673, pp. 143-167.

Data from aerial observations on numbers of calves observed with respect to (1) positions within herds of subgroups containing calves, (2) positions of calves within subgroups, (3) interactions between calves and other animals in the herd, and (4) changes in the behavior of calves with age. Apparent patterns were seen. Relevant observations from other field and captive studies are discussed.

Leatherwood, J. S. and D. K. Ljungblad. 1979. Nighttime Swimming and Diving Behavior of a Radio-tagged Spotted Dolphin (*Stenella attenuata*). *Cetology*, No. 34, 6 pp.

The dolphin, radio-tracked from shipboard for 13 consecutive hours, covered 100.5 km at estimated speeds of 2.3 to 10.7 knots, with burst speeds exceeding 12 knots. The animal dove for from 1 to 204 seconds, exhibiting three diving modes tentatively identified as running, traveling, and feeding.

Ljungblad, D. K. and S. E. Moore. 1983. Killer Whales (*Orcinus orca*) Chasing Gray Whales (*Eschrichtius robustus*) in the Northern Bering Sea. *Arctic* **36**:361-364.

Behaviors observed when 16 killer whales approached and chased feeding gray whales. No whale sounds were picked up by a sonobuoy although widely spaced killer whales exhibited apparently coordinated movements.

Ljungblad, D. K., B. Wursig, S. L. Swartz, and J. M. Keene. 1988. Observations on the Behavioral Responses of Bowhead Whales (*Balaena mysticetus*) to Active Geophysical Vessels in the Alaskan Beaufort Sea. *Arctic*. **41** (3):183-194.

Results from four field experiments support the conclusion that short-term behavioral changes occur when bowhead whales are exposed to airgun blasts from vessels within 10 km. The effects of airgun disturbance wane within an hour.

Murchison, A. E. and R. L. Pepper. 1972. Escape Conditioning in the Bottlenosed Dolphin (*Tursiops truncatus*). *Cetology* No. **8**, 5 pp.

To evaluate the effectiveness of procedures other than food reward in establishing behavioral control, the use of an aversive stimulus was investigated. The animal was successfully conditioned to approach an emitting hydrophone in order to terminate the presentation of a moderately intense sound delivered underwater.

Murchison, A. E. and S. A. Patterson. 1980. The Effect of Extended Reinforcement Schedules on the Receiver Operating Characteristics (ROC) of an Echolocating Atlantic Bottlenosed Dolphin (*Tursiops truncatus*). (Abs.) *Jour. Acoust. Soc. Am.* **68** (Suppl. 1): 597.

After a dolphin was conditioned to report (by paddle press) presence or absence of a target, its performance was tested using different variable and fixed-ratio reinforcement schedules. The dolphin's ROC remained essentially unchanged for all schedules, but when it was kept on the more extended schedules for more than eight consecutive 100-trial sessions, all responses became "target absent."

Nachtigall, P. E. 1971. Spatial Discrimination and Reversal Based on Differential Magnitude of Reward in the Dolphin (*Tursiops truncatus*). Eighth Annual Conf. on Biological Sonar of Diving Mammals, Menlo Park, CA, pp. 67-72.

Tursiops responds to differential reward magnitudes (four smelt versus one smelt) in a manner characteristic of other animals similarly studied.

Nachtigall, P.E. 1989. Echolocation Sameness-Difference and Matching-to-Sample: Demonstration of Dolphin Cognitive Processes. (Abs.) Animal Language Workshop, April 6-10, Honolulu, HI.

A presentation summarizing echolocation sameness-difference and delayed matching-to-sample experiments that demonstrated concept formation by echolocating dolphins.

Nachtigall, P.E., J. Lien, W.W.L. Au, and A.J. Read. 1995. *Harbor Porpoises: Laboratory Studies to Reduce Bycatch*. DeSpil Publishers, Woerden, The Netherlands, 167 pp.

This volume was organized in response to the growing international problem of harbor porpoises becoming entrapped and dying in fishing nets. It presents a summary of laboratory experiments specifically designed and carried out to examine net entrapment and ways to prevent animals from becoming entangled. Studies included an examination of acoustic signals, echolocation signal characteristics, behavior in response to ropes, entanglement and acoustic alarms to warn porpoises about nets.

Pawloski, D. A. and P. W. B. Moore. 1987. Combined Stimulus Control of Peak Frequency and Source Level in the Echolocating Dolphin (*Tursiops truncatus*). 15th Annual IMATA Conf., New Orleans, LA, Oct. 26, 1987, pp. 3-9.

The training methods by which an echolocating dolphin was trained to control its emitted source level and the frequency content of the echolocation click are presented.

Pawloski, J. L. 1990. Training a False Killer Whale (*Pseudorca crassidens*) for an Underwater Audiogram. (Abs.) 18th Annual IMATA Conf., Chicago, Nov. 4-9, 1990.

Details the training and testing for an underwater masked hearings threshold study using a false killer whale. Also discusses training problems related to this type of testing.

Pepper, R. L. and F. A. Beach, III. 1972. Deprivation and Other Aspects of Food Reinforcement in the Dolphin. Ninth Conf. on Biological Sonar and Diving Animals, 10 pp.

Dolphin behavior in a simple automated task was found to be responsive to controlled variations in food reinforcement.

Pepper, R. L. and F. A. Beach, III. 1972. Preliminary Investigations of Tactile Reinforcement in the Dolphin. Cetology. No. **7**, 8 pp.

Tactile reinforcement, gradually substituted for fish in a paddle-press task, at first maintained good response. After extensive testing, behavioral breakdown occurred. Aggressive behavior directed toward the trainer was interpreted as sexual frustration.

Pepper, R. L. and R. H. Defran. 1975. Dolphin Trainers Handbook, Part 1. Basic Training. NUC TP 432, 52 pp.

A handbook of information and guidance for dolphin trainers.

Ridgway, S. H. 1966. Studies on Diving Depth and Duration in *Tursiops truncatus*. 1966 Conf. on Biological Sonar and Diving Mammals, Menlo Park, CA, pp. 151-158.

Describes technique by which a bottlenosed porpoise was trained to dive to depths down to 550 feet and perform other tasks in preparation for participation in Sealab II. Total dive time to 550 feet and back averaged 163 seconds.

Ridgway, S. H., D. A. Carder, and M. M. Jeffries. 1985. Another Male "Talking" White Whale. (Abs.) Sixth Biennial Conf. on the Biology of Marine Mammals, Society of Marine Mammalogy, Vancouver, B.C., Canada, Nov. 22-26, p.67.

A male white whale nearing the attainment of sexual maturity spontaneously began to vocalize in a way that sounded like human speech heard at a distance. This phenomenon of white whale vocalization had been noted twice previously by others, but the physical characteristics of the sounds had not been presented. The spectral characteristics of distinctive phonations were measured and are described.

Ridgway, S., T. Kamolnick, M. Reddy, C. Curry, and R. Tarpley. 1993. Re-lactation and Induced Lactation in *Tursiops* and Analysis of Milk Collected with a Dolphin Milking Device. Tenth Biennial Conf. on the Biology of Marine Mammals, Galveston, Texas, Nov. 11-15, 1993, p. 91.

Milk was collected from two *Tursiops* that were induced to lactate by the presence of orphaned calves and analyzed for fat content. This was the first time milk was collected serially from dolphins conditioned to volunteer for the procedure.

Ridgway, S.H., T. Kamolnick, M. Reddy, C. Curry and R.J. Tarpley. 1995. Orphan-Induced Lactation in *Tursiops* and Analysis of Collected Milk. *Marine Mammal Science*. **11** (2): 172-182.

Reports on composition of milk voluntarily collected from two adult females induced to lactate by the presence of orphaned calves. This is the first report of cetacean females re-lactating to nurse calves not their own. It is also the first analysis of milk produced by induced lactation.

Ross, J., S. Klappenback, and M. Xitco. 1996. The U.S. Navy's Newest Recruits: Exploring Novel Directions for the Marine Mammal Program. (Abs.) 24th Annual IMATA Conf., Gold Coast, Australia, Nov. 3-8.

Reports on Navy's PROGENY project involving five 4- and 5-year-old bottlenose dolphins (*Tursiops truncatus*) being studied and trained as a group. Reviews conceptual techniques such as co-operative target detection, "mimicry" or behavioral modeling, and "match-to-sample" abilities that may enhance target Chun, N. K. W. 1978. Aerial Visual Shape Discrimination and Matching-to-Sample Problem-Solving Ability of an Atlantic Bottlenosed Dolphin. NOSC TR 236, 24 pp.

Schusterman, R. J. 1981. Behavioral Capabilities of Seals and Sea Lions: A Review of Their Hearing, Visual, Learning, and Diving Skills. *Psych. Rec.* **31**:125-143.

Compares behavioral/sensory capabilities of otariids (fur seals and sea lions) and phocids (earless seals).

Schusterman, R. J., B. K. Grimm, R. C. Gisiner, and F. B. Hangii. 1991. Retroactive Interference of Delayed "Symbolic" Matching-to-Sample in California Sea Lions (Abs.) *Bulletin of the Psychonomic Society*. 32nd Annual Meeting, San Francisco, CA., November 1991. **29**(6):486.

Experiments showed that two sea lions demonstrated nearly complete forgetting when irrelevant comparison stimuli were shown during the delay intervals in a two-choice delayed conditional discrimination task. Simple delays of 1 second to 2 minutes in one animal did not affect performance and the other animal showed some forgetting when the delay was from 1 to 45 seconds.

Thomas, J. A., L. M. Ferm, and V. B. Kuechle. 1987. Silence as an Antipredation Strategy by Weddell Seals. *Antarctic Jour. of the U.S.* **22** (5):232-234.

The hourly rate of underwater vocalizations over the day was collected near McMurdo Sound, Antarctica, from October through January for three seasons. In mid-December, for three years, the number of Weddell seal sounds decreased dramatically at the same time that killer whale and leopard seal vocalizations increased. The study proposes that as the two predatory species move near breeding colonies of Weddell seals, they shift from a highly vocal behavior to silence to avoid attracting attention to newly weaned seal pups.

Thomas, J. A., L. M. Ferm, and V. B. Kuechle. 1988. Patterns of Underwater Calls from Weddell Seals (*Leptonychotes weddelli)* During the Breeding Season at McMurdo Sound, Antarctica. *Antarctic Jour. of the U.S.* **23** (5): 146-148.

Seasonal changes in the hourly rate of vocalizations by Weddell seals was documented by automated cassette recorders. The rates changed in a way that predicted the onset of reproductive activities such as pupping, weaning, mating, and dispersal.

Wood, F. G. and S. H. Ridgway. 1967. Utilization of Porpoises in the Man-In-The-Sea Program. In: An Experimental 45-Day Undersea Saturation Dive at 205 Feet. ONR Report ACR-124, p. 407-411.

At Sealab II a bottlenosed dolphin named Tuffy was trained to carry objects between the surface and aquanauts working on the ocean floor. He also demonstrated his ability to carry a line from the habitat to a "lost" aquanaut. The conditioning of Tuffy and details of his transports to and from the Sealab site are described.

Wood, F. G., D. K. Caldwell, and M. C. Caldwell. 1970. Behavioral Interactions Between Porpoises and Sharks. In: *Investigations on Cetacea*, Vol. II, G. Pilleri (ed.). Institute of Brain Anatomy, Berne, Switzerland pp. 264-279.

Sometimes porpoises attack sharks, sometimes sharks attack (and eat) porpoises, and sometimes mutual tolerance is exhibited. The relationship of porpoises and sharks is still inadequately understood.

Wood, F. G. 1986. Social Behavior and Foraging Strategies of Dolphins. (Section introduction) In: *Dolphin Cognition and Behavior*, R. J. Schusterman, J. A. Thomas, and F. G. Wood (eds.). Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 331-333.

Dolphin social and feeding behaviors, first observed in oceanariums, have now been studied in free-ranging animals. While conditions of captivity may distort natural patterns, observations of behavior of captive animals can be useful in interpreting that of free-living dolphins. Captive conditions appear to stimulate dolphin propensities for play and the invention of games.

7. OPEN OCEAN TRAINING

Bailey, R. F. 1965. Training and Open Sea Release of an Atlantic Bottlenosed Porpoise *Tursiops truncatus* (Montagu). NOTS TP 3838, 17 pp.

Describes the first open water release of a trained porpoise.

Bowers, C. A. and R. S. Henderson. 1972. Project Deep Ops: Deep Object Recovery with Pilot and Killer Whales. NUC TP 306, 86 pp.

Killer whales and pilot whales were conditioned to locate and mark or recover cylindrical objects containing acoustic beacons that had been placed on the ocean floor. The two killer whales deployed practice recovery devices at maximum depths of 500 and 850 feet. A pilot whale deployed the device at 1654 feet, and on one occasion apparently made a volunteered dive (without the device) to 2000 feet.

Conboy, M. F. 1972. Project Quick Find: A Marine Mammal System for Object Recovery. NUC TP 268, Rev. 1, 31 pp.

Sea lions were trained to attach a nosecup-mounted grabber device to “pingered” objects on the ocean floor so that the objects (e.g., test ordnance, oceanographic instruments) can then be hauled to the surface by a line attached to the grabber. The system has been demonstrated to depths of 500 feet.

Evans, W. E. and S. R. Harmon. 1968. Experimenting with Trained Pinnipeds in the Open Sea. In: *The Behavior and Physiology of Pinnipeds*. R. J. Harrison et al. (eds.). Appleton-Century-Crofts, New York, pp. 196-208.

Details training procedures and results of deep-diving studies using seals and sea lions.

Hall, J. D. 1970. Conditioning Pacific White-Striped Dolphins (*Lagenorhynchus obliquidens*) for Open-ocean Release. NUC TP 200,14 pp.

Pacific white-striped dolphins were, for the first time, trained for open sea release.

Hall, R.W. and T. Kamolnick. 1993. Conditioning White Whales (*Delphinapterus leucas*) for the Open Sea. 21st Annual IMATA Conf., Kailua-Kona, HI, Nov. 7-12.

For the past 15 years, trainers in our laboratory have worked with white whales, Delphinapterus leucas, in an open ocean environment. These animals have proven to be versatile and easy to train for deep diving and demonstration of bio-systems programs. Behavioral tasks include boat following, object detection, recovery exercises of various underwater objects and medical behaviors.

Irvine, B. 1970. Conditioning Marine Mammals to Work in the Sea. *Marine Tech. Soc. Jour*. **4** (3):47-52.

Describes training procedures for open sea release for training.

Irvine, B. 1970. An Inflatable Porpoise Pen. NUC TP 181, 10 pp.

An inflatable, readily portable porpoise pen was designed, constructed, and tested in the open sea.

Marcus, S. R. 1972. Turk, the Sea Lion, Helps the Navy: Project Quick Find. Naval Ordnance Bulletin, March 1972, pp. 36-39.

A nontechnical article on the recovery of an instrumented ASROC depth charge by a sea lion. See Conboy, 1972, above.

Ridgway, S. H. 1969. Sea Lion Recovery Float. NUC TP 134, 5 pp.

To prevent sea lions from diving and swimming away during open sea training, a gas-generator float was developed employing a water-soluble washer as a timer and release mechanism, and a small balloon for flotation.

Ridgway, S. H., and C. C. Robinson. 1985. Homing by Released Captive California Sea Lions (*Zalophus californianus*) Following Release on Distant Islands. *Can. Jour. Zool.* **63**: 2162-2164.

Discusses the return of captive male sea lions to San Diego breeding islands 115 km and 240 km. off shore. Results suggest that sea lions are good navigators.

Wood, F. G. and S. H. Ridgway. 1967. Utilization of Porpoises in the Man-In-The-Sea Program. In: An Experimental 45-Day Undersea Saturation Dive at 205 Feet. ONR Report ACR-124, p. 407-411.

At Sealab II a bottlenosed dolphin named Tuffy was trained to carry objects between the surface and aquanauts working on the ocean floor. He also demonstrated his ability to carry a line from the habitat to a “lost” aquanaut. The conditioning of Tuffy and details of his transports to and from the Sealab site are described.

8. SURVEYS/TELEMETRY

Clarke, J. T., S. E. Moore, and D. K. Ljungblad. 1987. Observations of Bowhead Whale *(Balaena mysticetus)* Calves in the Alaskan Beaufort Sea During the Autumn Migration, 1982-85. *Rep. Int. Whal. Comm.* **37**: 287-293.

Analysis of sightings of 44 calves by geographic location, month, presence of adults, behavior, and ice cover.

Clarke, J. T., S. F. Moore, and D. K. Ljungblad. 1989. Observations on Gray Whale *(Eschrichtius robustus*) Utilization Patterns in the Northeastern Chukchi Sea, July-October 1982-1987. *Can. Jour. Zool.* **67**: 2646-2654.

A total of 821 gray whales were seen during aerial surveys. Monthly abundance was highest in July and lowest in October. Whales were usually seen feeding in open water and seldom in association with heavy ice. Calf abundance was highest in July.

Evans, W. E. 1970. Uses of Advanced Space Technology and Upgrading the Future of Oceanography. AIAA Paper No. 7-01273, 3 pp.

Two species of small whales equipped with small radio-telemetry packages so that their movements could be tracked have provided information on the animals' physical environment as a function of depth. Further data have been derived on areas of high biologic productivity and underwater topographical features. Telemetering via satellite would greatly extend the utility of this technique to oceanography.

Evans, W. E. 1971. Orientation Behavior of Delphinids: Radio-telemetric Studies. In: *Orientation: Sensory Basis*, H. E. Adler (ed.). Annals, New York Acad. Sci., Vol. 188, pp. 142-160.

The movements and diving behavior of wild common dolphins (*Delphinus delphis*) were ascertained by means of small radio transmitters attached to the animals.

Evans, W. E. and J. S. Leatherwood. 1972. The use of an Instrumented Marine Mammal as an Oceanographic Survey Platform. NUC TP 331, 11 pp.

By a small radio transmitter attached to its dorsal fin, a *Delphinus* was tracked for 3 days. The radio signal, transmitted when the dolphin surfaced, provided data on duration and depth of dives, and indicated probable nocturnal feeding on organisms of the deep-scattering layer at depths to 846 feet.

Evans, W. E. 1974. Telemetering of Temperature and Depth Data from a Free-ranging Yearling California Gray Whale (*Eschrichtius robustus*). *Mar. Fish. Rev.* **36** (4):52-58.

A young female gray whale, held in captivity for a year, was released carrying a radiotelemetry package that transmitted depth of dive and temperature-at-depth data.

Harrison, R. J. and S. H. Ridgway. 1972. Telemetry in Experimental and Trained Dives by Seals. Proceedings, Anatomical Society of Great Britain and Ireland. *Jour. Anat.* **111** (3):491.

See Harrison and Ridgway, 1972 below.

Harrison, R. J. and S. H. Ridgway. 1972. Seals, Dolphins, and Diving. *New Scientist*, August 10, 1972, pp. 283-285.

Describes how diving responses can be monitored by radiotelemetry.

Harrison, R. J., S. H. Ridgway, and P. L. Joyce. 1972. Telemetry of Heart Rate in Seals. *Nature* **238**:280.

Radiotelemetry devices were implanted in the hypodermis of the neck and back of gray seals to follow heart-rate changes in unrestrained seals diving on command. Bradycardia was found to be less marked during trained dives than in previously reported forced and restrained dives.

Hui, C. A. 1979. Undersea Topography and Distribution of Dolphins of the Genus *Delphinus* in the Southern California Bight. *Jour. Mammal.* **60**:521-527.

Delphinus occurs more frequently in areas of high relief. Availability of prey species over areas of different relief may be a major factor influencing distribution patterns. Herd size is greater (median 250) from May to October when anchovies are the major diet component; from November to April the median aggregation size is 40.

Hui, C. A. 1985. Undersea Topography and the Comparative Distributions of Two Pelagic Cetaceans. *Fish. Bull.* **83**:472--475.

The daytime distributions of pilot whales and common dolphins in the California Bight were found to be similar above undersea topography of high relief, but common dolphins occurred more frequently over areas of low relief. Differences in the distributions may be due to different foraging strategies.

Leatherwood, J. S. 1974. Aerial Observations of Migrating Gray Whales (*Eschrichtius robustus*) off Southern California, 1969-1972. *Mar. Fish. Rev.* **36** (4):45--49.

Presents data on movements, numbers, and distance from offshore, with details as to cows with calves and yearling animals observed.

Leatherwood, J. S., J. R. Gilbert, and D. G. Chapman. 1978. An Evaluation of Some Techniques for Aerial Censuses of Bottlenosed Dolphins. *Jour. Wildlife Management*. **42**:239-250.

Discusses field procedures and analytical techniques based on surveys conducted off the coasts of Louisiana, Mississippi, and Alabama. Population estimates from strip censuses are given for several areas, and suggestions are made for future censuses of dolphins inhabiting inshore waters.

Leatherwood, J. S., L. J. Harrington-Coulombe, and C. L. Hubbs. 1978. Relict Survival of the Sea Otter in Central California and Evidence of its Recent Redispersal South of Point Conception. *Bull. So. Calif. Acad. Sci.* **77**:109-115.

Details the past distribution of the sea otter; its apparent extirpation south of Alaska; the discovery of a remnant population in Monterey County, California, which has since proliferated; and recent sightings south of Point Conception.

Leatherwood, J. S. 1979. Aerial Survey of the Bottlenosed Dolphin (*Tursiops truncatus*) and the West Indian Manatee (*Trichechus manatus*) in the Indian and Banana Rivers, Florida. *Fish. Bull.* **77**:47-59.

The population of dolphins in the rivers during the week of the survey (10-15 Aug 1977) was estimated to be 438 +/- 127. There were 60 sightings of manatees totaling 151 animals; no attempt was made to estimate the size of the manatee population.

Ljungblad, D. K. 1981. Aerial Surveys of Endangered Whales in the Beaufort Sea, Chukchi Sea, and Northern Bering Sea. NOSC TD 449, 302 pp.

Describes aerial surveys and acoustic recordings of bowhead whales and other marine mammals from April to November 1980. Ice conditions radically altered the migration pattern seen in 1979.

Ljungblad, D. K., S. E. Moore, D. R. Van Schoik, and C. S. Winchell. 1982. Aerial surveys of Endangered Whales in the Beaufort, Chukchi, and Northern Bering Seas. NOSC TD 486, 374 pp.

Aerial surveys, acoustic recordings, and behavioral observations of bowhead whales were made prior to and during the spring migration and again during the fall migration. Summer survey efforts concentrated on gray whale distribution and behavior.

Ljungblad, D. K. 1983. Interaction Between Offshore Geophysical Exploration Activities and Bowhead Whales in the Alaskan Beaufort Sea, Fall 1982. *Jour. Acoust. Soc. Am.* **74** (Suppl. 1): 555.

Aerial surveys, supplemented by the use of sonobuoys, revealed no major changes in the behavior of bowheads exposed to seismic exploration sounds.

Ljungblad, D. K., S. E. Moore, and D. R. Van Schoik. 1984. Aerial Surveys of Endangered Whales in the Northern Bering, Eastern Chukchi, and Alaskan Beaufort Seas, 1983: With a 5-Year Review, 1979-1983. NOSC TR 995, 370 pp.

Presents survey results and observations on bowhead distribution, relative abundance, migration patterns, general behavior, and sound production. Includes survey results and observations on gray whale distribution, relative abundance, and general behavior for July.

Ljungblad, D. K., S. E. Moore, J. T. Clarke, D. R. Van Schoik, and J. C. Bennett. 1985. Aerial Surveys of Endangered Whales in the Northern Bering, Eastern Chukchi, and Alaskan Beaufort Seas, 1984: With a 6-Year Review, 1979-1984. NOSC TR 1046. 302 pp. incl. appendices.

See Ljungblad, et al., 1986, NOSC TR 1111, below.

Ljungblad, D. K., S. E. Moore, J. T. Clarke, and J. C. Bennett. 1986. Aerial Surveys of Endangered Whales in the Northern Bering, Eastern Chukchi, and Alaskan Beaufort Seas, 1985: With a 7-Year Review, 1979-1985. NOSC TR 1111, 407 pp. incl. appendices.

Both of the above items present survey results and observations on bowhead distribution, relative abundance, migration patterns, general behavior, and sound production for spring and fall months. Survey results and observations on gray whale distribution, relative abundance, and general behavior are also included, along with sightings of other marine mammals.

Ljungblad, D. K., S. E. Moore, and J. T. Clarke. 1986. Assessment of Bowhead Whale (*Balaena mysticetus*) Feeding Patterns in the Alaskan Beaufort and Northeastern Chukchi Seas via Aerial Surveys, Fall 1979-1984. *Rep. Int. Whal. Comm.* **36**:265-272.

Feeding bowheads occurred in larger groups, in shallower water, and in lighter ice cover than nonfeeding whales. Among feeding whales, differences in group size at different locations and in feeding patterns may have been due to the type of prey and its distribution, abundance, and location in the water column.

Ljungblad, D. K., S. E. Moore, and D. R. Van Schoik. 1986. Seasonal Patterns of Distribution, Abundance, Migration and Behavior of the Western Arctic Stock of Bowhead Whales (*Balaena mysticetus*) in Alaskan seas. *Rep. Int. Whal. Comm.* Special Issue **8**:177-205.

A detailed analysis of sightings during spring and fall months between 1979 and 1983.

Ljungblad, D. K., S. E. Moore, J. T. Clarke, and J. C. Bennett. 1987. Distribution, Abundance, Behavior, and Bioacoustics of Endangered Whales in the Alaskan Beaufort and Eastern Chukchi Seas, 1979-1986. NOSC TR 1177, 362 pp. incl. appendices.

Report covers survey results and observations on bowhead distribution, relative abundance and density, migration patterns, general behavior, and sound production recorded from air-dropped sonobuoys and from a station established on Barter Island. Survey results and observations on gray whale distribution, relative abundance, and general behavior are included, along with incidental sightings of other marine mammals.

Moore, S. E. and D. K. Ljungblad. 1984. Gray Whales in the Beaufort, Chukchi, and Bering Seas: Distribution and Sound Production. In: *The Gray Whale*, M. L. Jones, S. L. Schwartz, and J. S. Leatherwood (eds.). Academic Press, San Diego, CA, pp. 543-559.

Gray whale occurrence, distribution, behavior, and sound production were studied during aerial surveys in arctic waters in 1980 and 1981.

Moore, S. E., J. T. Clarke, and D. K. Ljungblad. 1986. A Comparison of Gray Whale (*Eschrichtius robustus*) and Bowhead Whale (*Balaena mysticetus*) Distribution, Abundance, Habitat Preference and Behavior in the Northeastern Chukchi Sea, 1982-1984. Rep. Int. Whal. Comm. **36**:273-279.

On aerial surveys conducted from July to October, differences between the two species were observed with respect to distance from shore, in open water vs. near ice cover, shallowness of water, and incidence of feeding behavior.

Moore, S. E., D. K. Ljungblad, and D. R. Van Schoik. 1986. Annual Patterns of Gray Whale (*Eschrichtius robustus*) Distribution, Abundance, and Behavior in the Northern Bering and Eastern Chukchi Seas, July 1980-1983. Rep. Int. Whal. Comm. Special Issue **8**:231-242.

Analysis of sightings, in the course of aerial surveys, of 1,543 gray whales with respect to distribution, estimated gross annual recruitment rate, behaviors, and sound production.

Reeves, R. R., D. K. Ljungblad, and J. T. Clarke. 1984. Bowhead Whales and Acoustic Seismic Surveys in the Beaufort Sea. *Polar Record* **22** (138):271-280.

Seismic survey activities were monitored in autumn 1982 for their possible effects on migrating bowheads. Distribution, behavior, and numbers of whales were recorded; one possible behavioral response to seismic shooting was observed.

Richardson, W. J., R. A. Davis, C. R. Evans, D. K. Ljungblad, and P. Horton. 1987. Summer Distribution of Bowhead Whales (*Balaena mysticetus*) Relative to Oil Industry Activities in the Canadian Beaufort Sea, 1980-84. *Arctic* **40** (2):93-104.

Distribution of bowheads both outside and within the "main industrial area" varied from year to year. Their numbers decreased, whether from increasing industrial activity or from variations in the whales' zooplankton prey is not clear.

Ridgway, S. H., R. J. Harrison, and P. L. Joyce. 1975. Sleep and Cardiac Rhythm in the Gray Seal. *Science* **187**:553-555.

Brainwaves, heartbeat, and eye movements of seals sleeping underwater, on the surface, or when hauled out were recorded by radiotelemetry.

Ridgway, S. H. and P. L. Joyce. 1975. Studies on Seal Brain by Radiotelemetry. *Rapp. P.-v. Reun Cons. Int. Explor. Mer.* **169**:81-91.

Describes technique by which an instrument package-mounting device was attached to the whale.

Turl, C. W. 1987. Winter Sightings of Marine Mammals in Arctic Pack Ice. *Arctic* **40**(3):219-220.

In February and March, six species of marine mammals were sighted in the pack ice of Baffin Bay and Davis Strait.

9. HYDRODYNAMICS

Fish, Frank E. and Clifford A. Hui. 1991. Dolphin Swimming-A Review. *Mammal Rev.* **21** (4): 181- 195.

Discusses various aspects of dolphin hydrodynamics—drag minimization, propulsion, swimming speed and behavior.

Haun, J.E., E.W. Hendricks, F.R. Borkat, R.W. Kataoka, D.A. Carder, C.A. Dooley, E. Lindner, and M.W. Stromberg. 1993. Dolphin Hydrodynamics: FY83 and FY84 Report. NRaD TR 998.

Reports on four years of research into hydrodynamic adaptations available to the dolphin, including study of skin histology, bulk property measurements and skin pressure sensitivity and biopolymer characterization and synthesis. Histology work demonstrates dolphin skin potential to function as a drag reducing coating.

Haun, J. E., E. W. Hendricks, F. R. Borkat, R. W. Kataoka, D. A. Carder, and N. K. Chun 1983. Dolphin Hydrodynamics Annual Report, FY 82. NOSC TR 935, 82 pp.

Describes various studies undertaken in the course of an investigation of the hydrodynamic characteristics of dolphins.

Haun, J. E., and E. W. Hendricks. 1990. Hydrodynamics. In: *Yearbook of Science and Technology--1991*. McGraw-Hill, Inc., New York, pp. 188-190.

Discusses dolphin skin morphology and effects on drag reduction.

Hendricks, E. W., and J. E. Haun. 1988. Dolphin Hydrodynamics. *Physics Today* **41** (1):S39.

Summary of past and recent investigations of dolphin hydrodynamics and drag reduction.

Hui, C. A. 1987. Power and Speed of Swimming Dolphins. *Jour. Mammal.* **68**:126-132.

Analysis of measured swimming speeds for dolphins of the *Stenella-Delphinus* morphology, using a conservative hydrodynamics model and a metabolic rate 13.4 times the projected resting metabolic rate, indicated that energy expenditure was entirely within expected ranges and no extraordinary mechanisms are necessary to explain observations.

Lang, T. G. 1963. Porpoise, Whales, and Fish: Comparison of Predicted and Observed Speeds. *Naval Engineers Jour.* May 1963, pp. 437-441.

Concludes that reported speeds of cetaceans and fish can be explained by an unusual extent of laminar flow.

Lang, T. G., and D. A. Daybell. 1963. Porpoise Performance Tests in a Seawater Tank. NOTS TP 3063, 50 pp.

A hydrodynamic study conducted with a trained *Lagenorhynchus obliquidens* in a long seawater tank revealed no unusual physiological or hydrodynamic phenomena. Because the

tank conditions may have affected the animal's performance, further tests in the open sea were recommended.

Lang, T. G. 1966. Hydrodynamic Analysis of Cetacean Performance. In: *Whales, Dolphins, and Porpoises*, K. S. Norris (ed.). Univ. of Calif. Press, Berkeley, CA., pp. 410-432.

A detailed discussion of cetacean hydrodynamic performance, presented at the First International Symposium on Cetacean Research held in Washington, DC in August 1963.

Lang, T. G. 1966. Hydrodynamic Analysis of Dolphin Fin Profiles. *Nature* **209**:110-111.

Cross sections of dolphin fins were found to have a shape intermediate between two independently proposed hydrodynamic shapes believed to have superior characteristics.

Lang, T. G. and K. S. Norris. 1966. Swimming Speed of a Pacific Bottlenosed Porpoise. *Science* **151**:588-590.

See next item.

Lang, T. G. and K. Pryor. 1966. Hydrodynamic Performance of Porpoises (*Stenella attenuata*). *Science* **152**:531-533.

The above two papers describe open-ocean speed runs of trained porpoises. Top speeds recorded were 16.1 knots (*Tursiops gilli*) and 21.4 knots (*Stenella attenuata*). The results compared closely with highest predictions based on rigid-body drag calculations and estimated available power output.

Madigosky, W. M., G. F. Lee, J. Haun, F. Borkat, and R. Kataoka. 1983. Acoustic Surface Wave Measurements on Live Bottlenosed Dolphins. NSWC TR 83-312, 18 pp.

In connection with a hydrodynamics study, dolphin skin properties were measured by determining responses to acoustic surface waves generated at different locations on the dolphins.

Ridgway, S.H. and D.A. Carder. 1993. Features of Dolphin Skin with Potential Hydrodynamic Importance. IEEE Conf. on Engineering in Medicine and Biology, **12**:83-88.

Microscopic examination of dolphin skin shows ridges that may be of hydrodynamic advantage.

Rohr, J., M.I. Latz, E. Hendricks, J.C. Nauen, and J. M. Stevenson. 1995. Flow Visualization of Dolphin Swimming Using Bioluminescent Marine Plankton. In: *Flow Visualization VII*, J. Crowder (ed.). Seventh International Symposium on Flow Visualization, Begell House, Inc., New York, pp. 34-39.

Interest in visualizing the flow field around a swimming dolphin is motivated by speculation that dolphins are able to maintain laminar flow around their bodies at high speeds. The present study indicates that naturally occurring bioluminescence can potentially be used as a flow diagnostic.

Williams, T.M., W.A. Friedl, M.L. Fong, R.M. Yamada, P. Sedivy, and J.E. Haun. 1992. Travel at Low Energetic Cost by Swimming and Wave-Riding Bottlenose Dolphins. *Nature*. **355**: 821-823.

Addresses previous speculation on energetic advantages from wave-riding by swimming dolphins through determination of the aerobic and anaerobic costs of swimming and wave-riding. Results indicate behavioral, physiological and morphological factors make swimming an economical form of high-speed travel for dolphins.

Williams, T.M. 1993. Swimming and Diving Energetics of Bottlenose Dolphins: Low Cost Locomotion by a Thinking Athlete. (Abs.) *American Zoologist*. **33** (5): 141A.

Study comparing different forms of aquatic locomotion (swimming and diving) for bottlenose dolphins. Results showed ascent and descent speeds of diving dolphins were often outside the maximum range speeds for animals swimming next to a boat. The study presents an energetic hypothesis regarding sinking versus swimming behaviors in diving marine mammals.

Williams, T.M., W.A. Friedl, J.E. Haun, and N.K. Chun. 1993. Balancing Power and Speed in Bottlenose Dolphins (*Tursiops truncatus*). Recent Advances in Marine Mammal Science. The Zoological Society of London. No. 66: 383-384.

Study examined the relationships among aerobic transport costs, oxygen stores and locomotor speed of bottlenose dolphins to determine the effects of hydrodynamic, energetic and physiological limitations on swimming and diving performance.

Williams, T.M., S.F. Shippee, K.L. Lawson, N.C. Chun, W.A. Friedl, and J.E. Haun. 1993. Non-Steady Swimming Increases Aerobic Dive Duration in Bottlenose Dolphins. (Abs.) Tenth Biennial Conf. on the Biology of Marine Mammals, Galveston, TX, Nov. 11-15, p. 113.

Reports on study of swimming strategies (wave-riding, efficient locomotor speeds) to determine whether they enabled the diving dolphin to conserve oxygen reserves during prolonged submergence. Results indicated interrupted swimming patterns (active swimming combined with passive gliding) may increase locomotor efficiency and prolong dive duration.

10. REINTRODUCTION/RETURN TO THE WILD

Brill, R.L. 1993. Reintroducing Captive Dolphins: Responsible Management or Emotional Placebo? (Abs.) Annual IMATA Conf., Kailua-Kona, HI, Nov. 7-12, 1993.

This presentation was based on the Navy's report on reintroduction (see Brill and Friedl, 1993). It compared the emotionally based arguments of "dolphin release" advocates with the objectives and applications of the recognized tools of conservation biology.

Brill, R.L. 1993. The Question of Reintroducing Captive Marine Mammals: A Model for Consideration (Abs.). Tenth Biennial Conf. on the Biology of Marine Mammals, Galveston, TX , Nov. 11-15.

This presentation was based on the Navy's report on reintroduction (see Brill and Friedl, 1993). It specifically described the model for reintroduction presented in the report and reviewed the criteria and requirements deemed necessary for biologically valid and successful reintroduction programs.

Brill, R.L. and W.A. Friedl. 1993. Reintroduction to the Wild as an Option for Managing Navy Marine Mammals. NRaD TR 154 9, 75 pp. with appendices.

Details results of a congressionally directed Navy study to determine requirements for reintroducing formerly captive bottlenose dolphins into the wild. Addresses such issues as candidate selection, behavioral training, disease transmission and genetics, nutritional and environmental issues, and post-reintroduction tracking. Concludes reintroduction is not a cost-effective marine mammal management option for the Navy under the conditions described, but recommends the Navy foster research and development into the methods and technologies required for reintroduction.

Brill, R.L. 1994. Return to the Wild as an Option for Managing Atlantic Bottlenose Dolphins. American Zoo and Aquarium Association Conf., Sept. 18-22, 1994.

This paper was presented as part of a "Symposium on Reintroduction" at the conference. It addresses the definition of reintroduction in terms of conservation biology, compares the claims of success and arguments made by "dolphin release activists" with the available empirical data, and questions whether and under what circumstances dolphins of non-endangered species dependent upon human care should be returned to the wild.

Ridgway, S. H. and J. N. Prescott. 1977. The Quandary of Whether to Retain or Release Rehabilitated Strandlings. (Abs.) In: *Biology of Marine Mammals: Insights Through Strandings*, J. B. Geraci and D. J. St. Aubin. Report prepared for Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-293-890, pp. 298-299.

Pending availability of information necessary for establishing a release program that will maximize survival of rehabilitated strandlings, the authors recommend that such animals be distributed to public display and research institutions, thereby replacing others that might be taken from wild stocks.

11. MISCELLANEOUS

Blanchard, R. E. 1975. Development of a Selection Procedure for Marine Mammal Trainers. NUC TP 490, 70 pp.

Describes a program of personnel research leading to a selection procedure for marine mammal trainers.

Bowers, C. A. and R. E. Austin. 1983. Capture, Transport, and Initial Adaptation of Beluga Whales. NOSC TR 811, 16 pp.

Describes techniques used in the capture, transport, and handling and feeding of six belugas, three captured in 1977 and three in 1980. The first three took over three months to complete adaptation. The second three, which benefited from techniques developed with the first group, reached the same stage in less than 2 months.

Evans, W. E., J. D. Hall, A. B. Irvine, and J. S. Leatherwood. 1972. Methods for Tagging Small Cetaceans. *Fish. Bull.* **70** (1): 61-65.

Describes tests of four techniques for tagging delphinids: plastic button tags, spaghetti tags, radio tags, and freeze branding.

Goforth, H.W. 1986. Marine Mammal Capabilities: A Survey of Selected Cetaceans and Pinnipeds. NRaD TR 1000. 138 pp.

Reports on an evaluation of characteristics of selected species of cetaceans and pinnipeds to determine potential for use as research animals. Employing six rating characteristics, recommends eight species for potential research study.

Haun, J.E., H.O. Porter, L.W. Bivens, and T.J. LaPuzza. 1996. The U.S. Navy Marine Mammal Program: A Brief History and Description of its Operational Systems. (Abs.). 24th Annual IMATA Conf., Gold Coast, Australia, Nov. 3-8.

Reports on the Navy's program to use marine mammals both for research and in operational systems.

Kastelein, R., J.A. Thomas, and P.E. Nachtigall. 1996. *Sensory Systems of Aquatic Mammals*. DeSpil Publishers, Woerden, The Netherlands, 588 pp.

This volume was the result of the third consecutive symposium solely devoted to aquatic mammals sensory systems. It was held at the Harderwijk marine mammal park in the spring of 1994. Nearly 400 pages were devoted to acoustics and hearing. Contributions came from all parts of the world including China, Japan, Russia, Israel, Canada, the United States and New Zealand. It is a review and summary of ongoing sensory processes work with marine mammals.

LaPuzza, T.J. 1996. Mammiferi Marines (A Brief History of the U.S. Navy Marine Mammal Program). *Cetacea Informa*. **5** (9): 17-21.

A description of the history and present status of the program, with details on current operational systems. (Italian and English)

Leatherwood, J. S., W. E. Evans, and D. W. Rice. 1972. The Whales, Dolphins, and Porpoises of the Eastern North Pacific: A Guide to Their Identification in the Water. NUC TP 282, 175 pp.

A guide, with descriptions and illustrations, for identifying cetaceans found in the eastern North Pacific Ocean.

Leatherwood, J. S. and D. W. Beach. 1975. A California Gray Whale Calf (*Eschrictius robustus*) Born Outside the Calving Lagoons. *Bull. So. Calif. Acad. Sci.* **74** (1): 45-46.

The birth of a living calf was observed off San Diego, far north of the lagoons where calving normally occurs.

Leatherwood, J. S., D. K. Caldwell, and H. E. Winn. 1976. Whales, Dolphins and Porpoises of the Western North Atlantic. NOAA TR NMFS CIRC-396, 176 pp.

A field guide to permit identification of cetaceans seen in the western North Atlantic, including the Caribbean Sea, the Gulf of Mexico, and coastal waters of the U.S. and Canada. Includes a key to aid in identification of stranded cetaceans, as well as appendices telling to whom to report data on live and dead cetaceans.

Reddy, M. (ed.). 1991. Cetacean Transport Standard Operating Procedure. NOSC TM 637, 10 pp.

Details proper care and procedural protocols for dolphin transports.

Ridgway, S. H., H. J. Flanagan, and J. G. McCormick. 1966. Brain-Spinal Cord Ratio in Porpoises: Possible Correlations with Intelligence and Ecology. *Psychon. Sci.* **6** (11): 491-492.

It has been suggested that brain weight-to-spinal cord weight ratios may provide a rough index of intelligence in vertebrate animals. This ratio in the bottlenosed porpoise average 40:1, as compared to the 50:1 ratio in man.

Ridgway, S. H. 1966. Dall Porpoise, *Phocaenoides dalli* (True): Observations in Captivity and At-Sea. *Norwegian Whaling Gazette*, No. 5, pp. 97-110.

Describes the natural history, capture, recorded sounds, and anatomy of Dall's porpoises, three of which were maintained at the Navy's Marine Bioscience Facility for periods ranging from 26 days to 10 months. No members of this species had previously survived in captivity.

Ridgway, S. H. and R. J. Harrison (eds.). 1981. *Handbook of Marine Mammals*, Vol. 1: *The Walrus, Sea Lions, Fur Seals, and Sea Otter*. 236 pp. Academic Press, London.

Ridgway, S. H. and R. J. Harrison (eds.) 1981. *Handbook of Marine Mammals*, Vol. 2: *Seals*. 364 pp. Academic Press, San Diego, CA.

Ridgway, S. H. and R. J. Harrison (eds.). 1985. *Handbook of Marine Mammals*, Vol. 3: *The Sirenians and Baleen Whales*. 362 pp. Academic Press, San Diego, CA.

Ridgway S. H. and R. J. Harrison (eds.). 1989. *Handbook of Marine Mammals*, Vol. 4: *River Dolphins and Larger Toothed Whales*. Academic Press, London.

In the above volumes, chapters on the various species include taxonomy, evolution, morphology and anatomy, abundance and life history, behavior, reproduction, and diseases. (Although not derived from the Navy's Marine Mammal Program, these works are included because senior editor Ridgway drew on the extensive knowledge gained from his participation in the program since its inception.)

Ridgway, S.H. and R.J. Harrison (eds.). 1994. *Handbook of Marine Mammals*, Vol. 5: *The First Book of Dolphins*. Academic Press, London, 416 pp.

This is a continuation of the book series describing the biology of each marine mammal species. Each chapter is by an author who is an expert on that particular species. This book covers many of the smaller dolphins.

Ridgway, S. H. and H. O. Porter. 1985. Biology of Navy Dolphins *Tursiops* (Abs.) Sixth Biennial Conf. on the Biology of Marine Mammals, Society for Marine Mammalogy, Vancouver, B.C., p. 3.

Summarizes the kind of biological information that can be obtained from captive *Tursiops*.

Ridgway, S.H. 1987. *The Dolphin Doctor*. Yankee Books, 160 pp. (hardcover); 1988. Fawcett, New York, 195 pp. (paperback).

Although not written as a scientific publication from the Navy Marine Mammal Program, this book documents the author's personal experiences in the early days of the program at Point Mugu, California. The author especially emphasizes his experiences with Tuffy, a dolphin that worked with the aquanauts in the Sea Lab II program in 1965.

Ridgway, S. H. 1989. Navy Marine Mammals. (Letters to the Editor) *Science*. **243**: 875.

Letter corrects inaccurate statements in a news item in Vol. 242, pp. 1503-1504 on the Navy Marine Mammal Program and especially concerning Navy dolphins deployed to the Persian Gulf in 1987/1988.

Ridgway, S.H. and S.E. Moore. 1995. Marine Mammal Science and U.S. Navy Ship Shock Trials. *Marine Mammal Science*. **11** (4):590-593.

Scientific correspondence describing the use of Navy expertise and knowledge of marine mammals to monitor ship-shock trials.

Ridgway, S.H. (ed.). 1996. Final Report from the Right Whale Necropsy Assessment Team: Results, Analysis, and Recommendations. NRaD TD 2934, 51 pp.

This document presents necropsy results, analysis, and recommendations of a panel of scientific experts convened to investigate the deaths of as many as six endangered right whales, *Eubalaena glacialis*. In one case, the cause of death was determined to be impact by an unidentified ship. The causes of death could not be determined in the other cases, due, in part, to inadequate necropsy protocols for large whales. Included is a draft report from a workshop to coordinate large whale stranding response in the southeast U.S., as well as recommendations for developing protocols to facilitate detailed evaluation of similar future incidents.

Ridgway, S.H., E. Lindner, K. A. Mahoney, and W.A. Newman. 1996. Gray Whale Barnacles *Cryptolepas rachianecti* Infest White Whales, *Delphinapterus leucas*, Housed in San Diego Bay. 27th Annual Conf. of the International Association for Aquatic Animal Medicine, Chattanooga, TN, May 11-15, 1996, **27**:43.

This paper describes the annual attachment of gray whale barnacles to white whales in San Diego Bay. The attachment is concurrent with the northward migration of gray whales and is the first report of this barnacle on a different whale species.

Ridgway, S.H., E. Lindner, K. A. Mahoney, and W.A. Newman. 1997. Gray Whale Barnacles *Cryptolepas rachianecti* Infest White Whales, *Delphinapterus leucas*, housed in San Diego Bay. *Bulletin of Marine Science*. 61 (2): 377-385.

Describes the annual attachment of gray whale barnacles to white whales in San Diego Bay. The attachment is concurrent with the northward migration of gray whales and is the first report of this barnacle on a different whale species.

Shippee, S.F., F.I. Townsend, F.L. Deckert, D.L. Gates, and O.M. Alcalay. 1995. A Tracking and Monitoring System for Free Swimming Dolphins Using a Trac-Pac Dorsal Fin Tag. 23rd Annual IMATA Conf., Tacoma, WA, Nov. 26, 1995.

Describes NRaD work with a commercial company in development of noninvasive dorsal fin pack designs for short-term attachment of electronic recording, monitoring and tracking equipment to free swimming dolphins.

Squire, I. 1964. A Bibliography of Cetacea: Literature Published Between 1949 and 1963. NOTS TP 3686, 118 pp.

Steele, J. W. 1971. Marine Environment Cetacean Holding and Training Enclosures. NUC TP 227, 25 pp.

Describes construction details of three types of marine-holding facilities for cetaceans: a permanent wood piling and galvanized-wire fencing enclosure, a permanent concrete-steel piling and fencing enclosure, and a floating pen supported by steel drums.

Van Bonn, W. 1995. What Did They Do With Those Dolphins? The Explorer Newsletter, Cabrillo National Monument, San Diego, CA, **4**:6-7.

Solicited article for the newsletter of the monument's Historical Society, providing information about the Navy's Marine Mammal Program and progress since moving the animal enclosures from the ocean to the bayside of the Pt. Loma peninsula.

Wood, F.G. 1973. *Marine Mammals and Man: The Navy's Porpoises and Sea Lions*. R.B. Luce Publishers, Washington, D.C. 264 pp.

A non-technical account of the Navy's Marine Mammal Program, with considerable background information on porpoises. Topics include capture and care, sonar, intelligence and communication, deep diving, hydrodynamics, and open ocean work.

Wood, F. G. 1979. The Cetacean Stranding Phenomenon: A Hypothesis. In: *Biology of Marine Mammals: Insights Through Strandings*, J. B. Geraci and D. J. St. Aubin (eds.). Report prepared for Marine Mammal Commission. Nat'l. Tech. Info. Serv. PB-293 890, pp. 129-188.

Discusses previous explanations of live strandings, presents stranding data, details circumstances of many strandings, and proposes that stranding may be attributed to a subcortical response to stress originating in amphibious ancestors and persisting to this day, despite its apparently maladaptive nature.

Wood, F. G. 1983. Annotated Bibliography of Publications from the U.S. Navy's Marine Mammal Program. NOSC TD 627, 49 pp.

Provides list of publications with short summary for each publication.

Wood, F. G. 1985. Annotated Bibliography of Publications from the U.S. Navy's Marine Mammal Program. NOSC TD 627, Revision A, 56 pp.

Provides updated list of publications since 1983 with short summary of each publication.

Wood, F. G. 1987. Annotated Bibliography of Publications from the U.S. Navy's Marine Mammal Program. NOSC TD 627, Revision B, 60 pp.

Provides updated list of publications since 1985 with short summary of each publication.

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13. ABSTRACT *(Maximum 200 words)*

This publication provides an updated bibliography of the Navy's Marine Mammal Program. This update contains works published through 31 December 1997. Some 220 publications are added to the previous edition, published in February 1992 (NRaD Technical Document 627, Revision C), plus two new chapters (Neural Networks and Reintroduction/Return to the Wild), reflecting areas of increased interest and importance.

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