continues to grow and in the United States, public support stands firmly behind both the MMPA and marine mammal facilities. More people are now enjoying the benefits of new and exciting training programs, shows, presentations, interaction opportunities, and scientific discoveries, all facilitated through behavior management.

By maintaining a healthy captive population of various marine mammal species, comparative data are generated to assist in understanding wild animals, and these facilities continue to give material support to important research and conservation initiatives. In addition, these facilities act as part of the Marine Mammal Stranding Network, assisting NOAA/NMFS in the rescue, housing, and care of stranded wild animals where expertise in medical care can be applied. These facilities also develop animal management and husbandry skills in staff members who are also able to assist in health assessment studies or during mass strandings, as directed by NMFS. Captive marine mammals and the facilities in which they live provide a template for handling highly endangered animals, or the establishment of a controlled breeding group, when the need arises. Finally, these facilities maintain a living repository of genetic material accessible through behavior management, where candidate animals can be carefully and scientifically selected and trained for introduction into the wild if needed. This successful model has been pioneered in zoological parks, saving numerous species from extinction, including the black-footed ferret and California condor (*Gymnogyps californianus*) (Top 10 Wildlife Conservation Success Stories, 2006). Behavior management plans are an intricate and important part of these programs, helping to generate public interest through fascinating presentations, dynamic behaviors, and invaluable research. These contributions are undoubtedly saving the lives of wild marine mammals.

XII. Conclusion

As formal behavior management gains wider application, wildlife managers will continue to increase their knowledge and application of animal learning principles, particularly as they relate to the conservation of highly endangered species, shrinking populations, and population recovery. Solutions to man/animal encounters, fisheries depletion, survival skill acquisition, translocation, reintroduction, and relocation efforts will require a specialized understanding of the learning and training processes, pioneered in the learning laboratories, and applied in the field of marine mammal training and behavior management.

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See Also the Following Articles

Captivity ■ Behavior, Overview ■ Captive Breeding ■ Ethics and Marine Mammals ■ Marine Parks and Zoos

References

Baldwin, B., and Baldwin, J. (1998). "Behavior Principles in Everyday Life." Simon & Schuster, New Jersey.

Chance, P. (1994). "Learning and Behavior," 3rd Ed. Brooks/Cole Publishing Company, Belmont.

Cole, K. C., Van Tilburg, D., BurchVernon, A., and Riccio, D. C. (1996). The importance of context in the US preexposure effect in CTA: Novel versus latently inhibited contextual stimuli. *Lear. Motiv.* **27**, 362–374.

Domjan, M. (1993). "The Principles of Learning and Behavior," 3rd Ed. Brooks/Cole Publishing Company, Belmont.

Honig, W. K., and Staddon, J. E. R. (1977). "The Handbook of Operant Behavior." Prentice-Hall, Inc, Englewood Cliffs.

Kazdin, A. E. (1994). "Behavior Modification in Applied Settings," 5th Ed. Brooks/Cole Publishing Company, Belmont.

Marine Mammal Permits and Authorizations. (2006). [Accessed online July 5, 2007]. Available from World Wide Web: http://www.nmfs.noaa.gov/pr/permits/mmpa_permits.htm

Marine Mammal Poll. Harris Interactive. (2005). [Accessed online July 10, 2007]. Available from World Wide Web: http://www.ammpa.org/_docs/HarrisPollResults.pdf

Pryor, K. (1995). "On Behavior: Essays and Research," 1st Ed. Sunshine Books, North Bend.

Ramirez, K. (1999). "Animal Training: Successful Animal Management through Positive Reinforcement." Shedd Aquarium Press, Chicago.

SeaWorld. (2006). The 7th Anniversary of J.J.'s Rescue." Press release, issued spring 2006.

Shepherdson, D. J., Mellen, J. D., and Hutchins, M. (1998). "Second Nature: Environmental Enrichment for Captive Animals." Smithsonian Institution Press, Washington, DC.

Spear, N. E., and Riccio, D. C. (1994). "Memory: Phenomena and Principles." Allyn & Bacon, Needham Heights.

Spradlin, T. R, Drevenak, J. K., Terbush, A. D., and Nitta, E. T. (1999). Interactions between the public and wild dolphins in the United States: Biological concerns and the Marine Mammal Protection Act. *In* "Wild Dolphin Swim Program Workshop," held in conjunction with the 13th Biennial Conference on the Biology of Marine Mammals, November 28, 1999. Silver Spring.

Top 10 Wildlife Conservation Success Stories in 2006. (2006). [Accessed online June 11, 2007]. Available from World Wide Web: http://www.aza.org/Newsroom/PR_TopTenStories2006

Turner, T., and Stafford, G. (2000). Rapid weight fluctuations linked to increased aggression in intact male California sea lions (*Zalophus californianus*). *Mar. Mamm. Pub. Disp. Res.* **4**, 14–20.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of the Administrative Law Judge In the Matter of: Richard O'Barry United States of America. (1999). [Accessed online June 25, 2007]. Available from World Wide Web: http://www.animallaw.info/cases/caus1999noaalexis1.htm

Willis, K. (2007). Life expectancy of bottlenose dolphins in Alliance of Marine Mammal Parks and Aquariums' North American member facilities: 1990—present. Presented at the 2007 meeting of the Alliance of Marine Mammal Parks and Aquariums.

Tucuxi and Guiana Dolphin
Sotalia fluviatilis and S. guianensis

Paulo A.C. Flores and Vera M.F. Da Silva

I. Characteristics and Taxonomy

The genus *Sotalia* of the family Delphinidae was once considered to comprise five species, but in the twentieth century, this was reduced to two, the riverine *Sotalia fluviatilis* and the marine *Sotalia guianensis*. Later these were further lumped into a single species

(*S. fluviatilis*), with marine and riverine ecotypes. Recent morphological and genetic studies, however, concluded that marine and riverine *Sotalia* are different species (Cunha *et al*., 2005; Caballero *et al*., 2007). Based on priority criteria, the name *Sotalia guianensis* (Van Bénéden 1864) was assigned to the marine animals, whereas riverine dolphins retained the oldest species name *Sotalia fluviatilis* (Gervais 1853). No fossil record is known.

The common name tucuxi comes from *tucuchi-una* after the Tupi language of the Mayanas Indians from the Amazon region of Brazil, where it is called *boto-tucuxi*, *boto-cinza*, or simply *boto*. In the other Amazon countries it is usually called *delfin* or *bufeo gris del rio. S. guianensis* is also known simply as *boto* or *golfinho* and as *boto comum* and *golfinho cinza* along the Brazilian coast; *bufeo gris*, *bufeo blanco*, or *bufeo negro* in Colombia and Peru; *tonina de rio*, *delfin blanco*, or *soplón* in the Venezuela Amazon, *tonina del lago* in Lake Maracaibo, and *bufeo negro*, *bufete*, or *soplón* in the Orinoco River basin in Venezuela; *lam* in Nicaragua; Guyana dolphin or Guiana white dolphin in Guyana; and *profuso* or *dolfijn* in Surinam. There is some controversy about a definitive international common name for *S. guianensis* in English. Various names have been used in the literature, most frequently marine tucuxi, gray dolphin, estuarine dolphin, and recently costero. We avoid the controversy here by using "Guiana dolphin," based on the Scientific name.

The two *Sotalia* species are very similar in coloration, differing mainly in body size and number of teeth, and somewhat resembling a small bottlenose dolphin, *Tursiops* (Fig. 1). They are light gray to bluish gray on the back and pinkish to light gray ventrally, with a distinct line from the mouth gape to the flipper's leading edge. There is a lighter area on the flank between the flippers and the dorsal fin and another mid-body at the level of the anus. The marine species has another light gray rounded streak on both sides of the caudal peduncle. In both species, the eyes are large, and there is black countershading around the eyes. A case of atypical white coloration was recently reported, although it was not confirmed whether it was albinism or another type of anomalously light pigmentation. The dorsal fin is triangular and sometimes slightly hooked on the tip. The tucuxi has a moderately slender beak, a rounded melon and 26–36 teeth in each mandibular ramus. The Guiana dolphin has more upper teeth and is larger than the tucuxi, with a maximum total length of 220 cm and about 80 kg body mass vs a maximum length of around 152 cm and mass of 55 kg.

II. Distribution and Abundance

The tucuxi occurs in the main tributaries of the Amazon/Solimões River basin in Brazil as far inland as southeastern Colombia, eastern Ecuador, and northeastern Peru, with records in all three types of water that occur in this region. Several rivers contain impassable falls, rapids, and shallow waters. On the tributaries of the right side of the Amazon basin, the Teotônio and Santo Antônio Falls on the Madeira River, the Santa Isabel Falls on the R. Xingú, and S. Luis Falls on the Tapajós river are impassable barriers, whereas on the left side the falls on the Rio Negro and Raudal La Liberdad on the Caquetá River (Colombia) are also important. The tucuxi does not occur in the Beni/Mamoré River basin in Bolivia and is not known in the upper Rio Negro. The presence of the species in the Orinoco River basin is still controversial, since a stretch of rapids and falls in the Negro River and the 354 km of numerous rapids and outcrops of

Figure 1 *Guiana dolphins*. (Photo by P.A.C. Flores).

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the Cassiquiare Channel block the species' movements. Its distribution is influenced by seasonal river level fluctuations, with channels and lakes occupied during rising and high waters but avoided at low water. The tucuxi is abundant in the Solimões and Japurá Rivers as well as in large black water lakes such as Tefé Lake (Brazil) and the El Correo lakes system (Colombia). Tucuxis do not go into flooded forest as does the sympatric boto, *Inia geoffrensis*, but these species share a preference for areas with reduced current and waterway junctions. Mean density along the margins of main rivers in the central Amazon, Brazil within 150 m survey strip of 1,319.7 km was 3.2 individuals per km^2, with 54% of the individuals occurring within 50 m of the edge (Martin *et al*., 2004). At the border of Colombia, Brazil, and Peru, Vidal *et al*. (1997) found along about 120 km of the Amazon River a density of 8.6/km^2 in lakes, 2.8 along main banks and 2.0 around islands (Fig. 2).

The Guiana dolphin is found in the Western Atlantic coastal waters of South and Central America from southern Brazil (27°35'S, 48°35'W) to Nicaragua (14°35'N, 83°14'W), including Colombia, Costa Rica, French Guyana, Guyana, Panama, Suriname, Trinidad, Venezuela, and possibly Honduras (15°58'N, 79°54'W). In the Orinoco River dolphins seen as far up as Ciudad Bolivar may be of this species. The Guiana dolphin is found mostly in estuaries, bays, and other protected shallow coastal waters, although it has also been recorded at the Abrolhos Archipelago, around 70 km off the coast of Bahia State, Brazil. The species' southernmost limit is influenced by the cold waters of the Malvinas current in South Brazil. It is notably recorded throughout the year in many coastal locations such as Baía Norte in Santa Catarina State, Cananéia Estuary and Baía de Guanabara (both in southeastern Brazil), Baía de Todos os Santos and around Fortaleza (northeastern Brazil), Bahia Cispatá and Golfo de Morrosquillo (Colombia), as well as on the Cayos Miskito Coast in Nicaragua. Standard abundance estimates are scarce for the Guiana dolphin, but the species seems to be abundant in various locations along its distribution, mainly in South-Southern Brazil outside of Guanabara Bay. Stocks or significant evolutionary units are evident from residency, site fidelity, genetic and acoustical data.

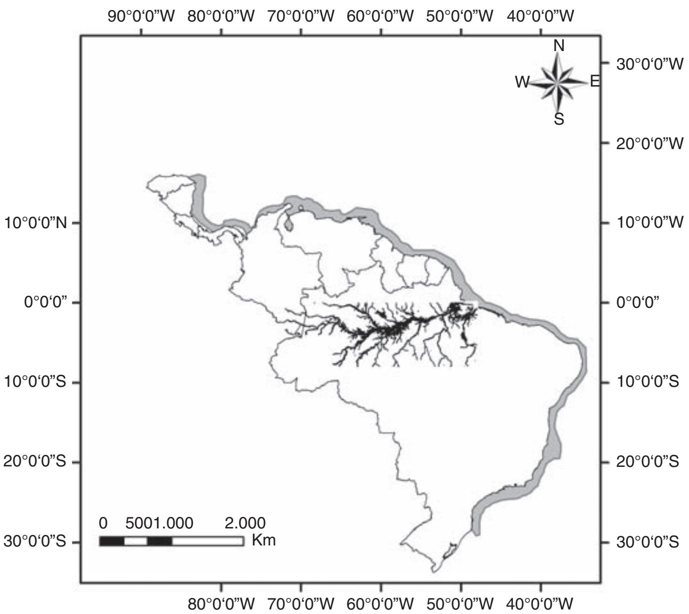

Figure 2 *Distribution of the tucuxi* Sotalia fluviatilis *and the Guiana dolphin* S. guianensis.

III. Ecology

The Guiana dolphin feeds on neritic prey distributed through the water column, mainly on neritic fishes such as clupeids and sciaenids, but cephalopods, shrimps, crabs, and flounders are occasionally taken. Usually young specimens of these teleost fishes, including over 20 species, are the most important diet items. Tucuxis feed mainly on schooling pelagic fish such as characiforms, freshwater clupeids, and sciaenids, no larger than 35 cm. Feeding may occur in pairs, usually mother and calf, and in larger groups or subgroups when different strategies and cooperation among individuals are employed. During feeding activities, Guiana dolphins often associate with birds such as the brown booby (*Sula leucogaster*), terns (*Sterna* spp.), frigate bird (*Fregata magnificens*), and kelp gull (*Larus dominicanus*). Mixed-species flocks of up to a hundred birds can be seen in such associations. In the Amazon, tucuxis may feed occasionally in association with terns (*Phaetusa simplex*). These associations are initiated by the birds and have no impact on the dolphins.

There are no known predators for either species, although bites from sharks of unidentified species have been seen on Guiana dolphins.

Because of the huge regional differences in habitats from temperate waters in the south to the tropical waters, including estuaries such as the Amazon estuary, Guiana dolphins are found in a wide range of water depth, temperature, salinity, and turbidity.

No mass stranding has been reported. Individuals often wash ashore, sometimes due to incidental catch in fisheries in both marine and freshwater environments.

IV. Behavior and Physiology

Sotalia dolphins show a variety of aerial behaviors such as full leaps, somersaults, fluke-ups, spy-hopping, surface rolling, and porpoising. In coastal areas, feeding and traveling are by far the most common behaviors, although resting and milling are rare. Socializing involves various tactile contacts, and herding of females by males has been occasionally seen in southern Brazil. Bow-riding has not been recorded, but Guiana dolphins may surf in waves and wakes produced by passing boats.

Spontaneous swimming interactions with domestic dogs (*Canis familiaris*) and a lone wild Guiana dolphin sociable toward humans were recorded in southeastern Brazil. Epimeletic behavior and hand feeding were also recorded in the same area (Santos *et al*., 2000). Apparent mating behavior with bottlenose dolphins was recorded off Costa Rica In Baía Norte, South Brazil, at the southernmost distributional limit, Guiana dolphins do not associate with bottlenose dolphins, and rare encounters even result in aggression by bottlenose dolphins or escape behavior by the Guiana dolphins (Flores and Fontoura, 2006). Epimeletic behavior toward an offspring was recorded at that locality.

Dives for Guiana dolphins last about 30–120 sec with shorter dives of 5–10 sec in between. Tucuxis are fast swimmers, spending less than a second at the surface, with an average dive time of about 2 min.

The *Sotalia* species are social dolphins, almost always in cohesive groups engaged in the same activities. Tucuxis are often found in groups of one to six individuals, although larger groups up to 20 individuals are also recorded (Faustino and da Silva, 2006). Groups of up to 50 or 60 Guiana dolphins are common, whereas the average group size is two to six. Large aggregations of up to 200 are reported at Baía de Sepetiba and around 400 individuals in Baía da Ilha Grande on the southeastern Brazilian coast, where these larger aggregations are usually engaged in cooperative feeding. Apparently, larger groups are more common in the south and southeastern Brazilian coast. Mixed groups of adults and calves are common. Individual associations are known only for the Cananéia Estuary population in Brazil; these are weak to moderate, except for a few pairs of individuals with apparently stronger associations, suggesting a relatively fluid society with individuals in fission–fusion (Santos and Rosso, in press).

Photo-identification studies have shown that Guiana dolphins may be resident within and between years for up to 10 consecutive years (e.g., Flores 1999; Flores and Bazzalo, 2004). Home ranges are poorly known and apparently among the smallest for small cetaceans with a mean of about 15 km^2 in southern Brazil and up to 265 km^2 in another location. Movement patterns vary among warm and cold seasons in the temperate region, whereas no variation was found in warm waters. In any case, daily movements are small. Freeze-branded tucuxis in Central Amazon were recorded for several years in the same area, suggesting residency and seasonal use of areas.

Comparative analysis of the whistles of Guiana dolphins in different areas along the Brazilian coast revealed significant effects of geographical location. However, is difficult to discriminate between adjacent populations. Guiana dolphins produce mainly upsweep whistles, shorter and less complex in shape than for other species of dolphins. The range of whistle fundamental frequencies recorded was 0.21–24 kHz and durations 38–1064 ms (Azevedo and Van Sluys, 2005).

Research with acoustic pingers in Fortaleza, Brazil, during 345 h of experiment showed that Guiana dolphins avoided areas where pingers were active (Monteiro-Neto *et al*., 2004).

V. Life History

Calving is year-round and gestation is estimated to be around 11–12 months for the Guiana dolphin, with calves ranging in size from 90 to 100 cm of total length. Calving interval is believed to be 22–24 months based on photo-identification data. Tucuxi calving occurs between September and November, during low water season, after a gestation time estimated at 11 months, with calves at birth measuring from 71 to 83 cm (da Silva and Best, 1994).

According to tooth growth layer groups (GLGs), life span can reach 30 and 35 years for the Guiana dolphin and tucuxi, respectively. Natural mortality rates are unknown for both species.

VI. Interactions with Humans

Historically, these species have not been exploited commercially, although incidental mortality in local and commercial fisheries such as those using gillnets and seines are a direct threat to *Sotalia* dolphins. Bottom-set nets for lobsters also occasionally capture Guiana dolphins. On the coasts of Amapá, Maranhão, and Pará States, northern Brazil, Guiana dolphins are killed for shark bait, although they have some protection from myths and legends. This is especially true for the tucuxis in the Amazon (Gravena *et al*., in press). There, their genital organs and eyes have a local market as love charms, and teeth and bones are used for arts and crafts. Guiana dolphins in some parts of their distribution, mainly on the northern and northeastern coasts of Brazil, may also be used for human consumption. Although these dolphins are fully protected by Federal laws in Brazil, forbidding the harassment, hunting, fishing, or capture of tucuxis and all cetaceans, pinnipeds, and sirenians in national waters, law enforcement may not be effective. In other countries such as Colombia, Ecuador, Peru, and Venezuela, tucuxis are not clearly protected by laws.

Acoustic pingers attached to gill nets may successfully reduce or prevent by catch of Guiana dolphins as suggested by a single study conducted with free ranging dolphins in northeastern Brazil (Monteiro-Neto *et al*., 2004).

Dams and hydroelectric power facilities in the Amazon region interrupt fish migration, reducing fish abundance, and consequently prey availability for dolphins. Mercury from gold mining, water pollution, seismic activities, oil spills, and boat traffic are other potential threats to tucuxis in the Amazon, while the same factors, except gold mining, plus marine culture farms and destruction of habitats, mainly mangroves and salt marshes, strongly affect the Guiana dolphins. Hand feeding and the behavioral effects caused by boat activities also deserve concern, as these may affect at least populations off the coasts. Bioaccumulation of contaminants and growing pollution outfalls are also concerns.

Sotalia dolphins are susceptible to capture stress, quickly become entangled and sometimes suffocate in nets, and are not robust to long periods of transportation or handling after capture. However, Guiana dolphins captured off the coast of Panamá in the late 1970s were kept in captivity in Europe for more than 20 years, and one animal is still alive today. A few Guiana dolphins are still kept in Colombian facilities, although since 2005 it has been illegal to maintain them in captivity.

The separation of the two species is too recent to appear in any of the Species Conservation Status lists, although both *Sotalia* species should be listed as "insufficiently known" by the World Conservation Union (IUCN) as was the status of the unified species. Because of its coastal habits, aggregating in estuaries and bays, and in river channels and lakes, *Sotalia* dolphins are vulnerable to almost all human activities throughout their range. A large proportion of the distributional area of the two species is close to human habitation. Consequently, these habitats are subject to intense fisheries, boat traffic and sewage, industrial waste, and high levels of contaminants. Examples are the Santos and Rio de Janeiro harbors in southeast Brazil, Recife and Rio Grande do Norte in the northeast Brazil, Maracaibo in Venezuela, Golfo de Morrosquillo in Colombia, and Belém, Santarém and Manaus in the Brazilian Amazon.

See Also the Following Articles

Delphinids, Overview ■ South American Marine Mammals

References

Azevedo, A. F., and Van Sluys, M. (2005). Whistles of the tucuxi dolphin (*Sotalia fluviatilis*) in Brazil: Comparisons among populations. *J. Acoust. Soc. Am.* **117**, 1456–1464.

Caballero, S., *et al*. (2007). Taxonomic status of the genus Sotalia: Species level ranking for "tucuxi" (*Sotalia fluviatilis*) and "costero" (*Sotalia guianensis*) dolphins. *Mar. Mam. Sci.* **23**, 358–386.

Cunha, H. A., *et al*. (2005). Riverine and marine *Sotalia* (Cetacea: Delphinidae) are different species. *Mar. Biol.* **148**, 449–457.

Faustino, C., and da Silva, V. M. F. (2006). Seasonal use of Amazon floodplains by the tucuxi *Sotalia fluviatilis* (Gervais 1853), in the Central Amazon, Brazil. *Lat. Am. J. Aquat. Mamm.* **5**, 95–104.

Flores, P. A. C. (1999). Preliminary results of a photo identification study of the marine tucuxi, *Sotalia fluviatilis*, in southern Brazil. *Mar. Mamm. Sci.* **15**, 840–847.

Flores, P. A. C., and Bazzalo, M. (2004). Home ranges and movements patterns of the marine tucuxi *Sotalia fluviatilis* in Baía Norte, southern Brazil. *Lat. Am. J. Aquat. Mamm.* **3**, 37–52.

Flores, P. A. C., and Fontoura, N. F. (2006). Ecology of marine tucuxi, *Sotalia guianensis*, and bottlenose dolphin, *Tursiops truncatus*, in Baía Norte, Santa Catarina State, southern Brazil. *Lat. Am. J. Aquat. Mamm.* **5**, 105–115.

Gravena, W., Hrbek, T., da Silva, V. M. F. and Farias, I. P. (2008). Amazonian pink dolphin love fetishes: From folklore to molecular forensics. *Mar. Mamm. Sci.*

Martin, A. R., da Silva, V. M., and Salmon, D. L. (2004). Riverine habitat preferences of botos (*Inia geoffrensis*) and tucuxis (*Sotalia fluviatilis*) in the Central Amazon. *Mar. Mamm. Sci.* **20**, 189–200.

Monteiro-Neto, C., Itavo, R. V., and Moraes, L. E. S. (2003). Concentrations of heavy metals in *Sotalia fluviatilis* (Cetacea: Delphinidae) off the coast of Ceará, northeast Brazil. *Env. Poll.* **123**, 319–324.

Monteiro-Neto, C., *et al*. (2004). Behavioral responses of *Sotalia fluviatilis* (Cetacea, Delphinidae) to acoustic pingers, Fortaleza, Brazil. *Mar. Mamm. Sci.* **20**, 145–151.

Nascimento, L. F. *et al*. (2007). Atypical coloration in a specimen of estuarine dolphin, *Sotalia guianensis*, on the littoral of the state of Rio Grande do Norte, north-east Brazil. JMBA2 – *Biodiv. Rec.* (Published online) 2 pp.

Rossi-Santos, M. R., and Podos, J. (2006). Latitudinal variation in whistle structure of the estuarine dolphin *Sotalia guianensis*. *Behaviour* **143**, 347–364.

Santos, M. C.de. O., and Rosso, S. (2008). Social organization of marine tucuxi dolphins, *Sotalia guianensis*, in the Cananéia estuary, southeastern Brazil. *J. Mammal.* **89,** 347–355.

Santos, M. C. O., Rosso, S., Siciliano, S., Zerbini, A. N., Zampirolli, E., Vicente, A., and Alvarenga, F. (2000). Behavioural observations of the marine tucuxi dolphin (*Sotalia fluviatilis*) in São Paulo estuarine waters, Southeastern Brazil. *Aq. Mamm.* **26**, 260–267.

da Silva, V. M. F., and Best, R. C. (1994). Tucuxi *Sotalia fluviatilis* (Gervais, 1853). *In* "Handbook of Marine Mammals—The First Book of Dolphins" (S. H. Ridgway, and R. J. Harrison, eds), Vol. 5, pp. 43–49. Academic Press, London.

Van Bressem, M.-F., *et al*. (24 authors) (2007). A preliminary overview of skin and skeletal diseases and traumata in small cetaceans from South American waters. *Lat. Am. J. Aquat. Mamm.* **6**, 7–42.

Vidal, O., Barlow, J., Hurtado, L. A., Torre, J., Cendón, P., and Ojeda, Z. (1997). Distribution and abundance of the Amazon River dolphin (*Inia geoffrensis*) and the tucuxi (*Sotalia fluviatilis*) in the upper Amazon River. *Mar. Mamm. Sci.* **13**, 427–445.

Yogui, G. T., Santos, M. C. O., and Montone, R. C. (2003). Chlorinated pesticides and polychlorinated biphenyls in marine tucuxi dolphins (*Sotalia fluviatilis*) from the Cananéia estuary, southeastern Brazil. *Sci. Tot. Env.* **312**, 67–78.

The Tuna-Dolphin Issue

Tim Gerrodette

I. The Problem

In the tropical waters of the Pacific Ocean west of Mexico and Central America, large yellowfin tuna (*Thunnus albacares*) swim together with several species of dolphins: pantropical spotted (*Stenella attenuata*), spinner (*S. longirostris*), and common (*Delphinus delphis* and *D. capensis*) dolphins. This ecological association of tuna and dolphins is not clearly understood, but it has had two important practical consequences: it has formed the basis of a successful tuna fishery, and it has resulted in the deaths of a large number of dolphins. This is the heart of the tuna-dolphin issue.

The bycatch of dolphins in the eastern tropical Pacific (ETP) purse-seine tuna fishery stands apart from marine mammal bycatch in other fisheries, not only in scale but also in the way the dolphins interact with the fishery. Marine mammals interact with most fishing gear only incidentally, but in the ETP tuna fishery the dolphins are an intrinsic part of the fishing operation (Perrin, 1969). The fishermen intentionally capture both tuna and dolphins together, then release the dolphins from the net (National Research Council, 1992). Further, unlike in most other fisheries, the vast majority of dolphins captured by the ETP tuna fishery are released alive; thus, an individual dolphin may be chased, captured, and released many times during its lifetime.

The number of dolphins killed since the fishery began in the late 1950s is estimated to be over 6 million animals, the highest known for any fishery. For comparison, the total number of whales of all species killed during commercial whaling in the twentieth century was about 2 million. The bycatch of dolphins in the ETP tuna fishery has now been successfully reduced by more than 99%, but even at the present level of 1500 dolphins/year, it remains among the largest documented cetacean bycatches in the world.

II. Purse-Seining for Tuna

Prior to the development of modern purse seines, tropical tuna were caught one at a time using pole-and-line methods. In the late 1950s, the twin technological developments of synthetic netting that would not rot in tropical water and a hydraulically driven power-block to haul the net made it possible to deploy very large purse-seine nets around entire schools of tuna, and thus to catch many tons of fish at a time. Purse-seining for tuna in the ETP can be conducted in one of three ways: the net may be set around schools of tuna associated with dolphins ("dolphin sets," which catch large yellowfin tuna), around schools of tuna associated with logs or other floating objects ("log sets," which catch mainly skipjack but also bigeye and small yellowfin tuna), or around unassociated schools of tuna ("school sets," which catch small yellowfin and skipjack tuna). The proportions of different set types have varied over the history of the fishery, but in recent years, about half have been dolphin sets, one quarter log sets and one-quarter school sets.

Dolphins are killed almost exclusively in dolphin sets. During "porpoise fishing" (the fishermen's term), schools of tuna are located by first spotting the dolphins or the seabird flocks which are also associated with the fish. Speedboats are used to chase down the dolphins and herd them into a tight group; then the net is set around them (Fig. 1). The tuna-dolphin bond is so strong that the tuna stay with the dolphins during this process, and tuna and dolphins are captured together in the net (Fig. 2). Dolphins are released from the net during the backdown procedure (Fig. 3). If all goes well, the dolphins are released alive, but the process requires skill by the captain and crew, proper operation of gear, and conducive wind and sea conditions. As with any complicated procedure at sea, things can go wrong, and when they do, dolphins may be killed.

From an ecosystem perspective, management of the ETP purse-seine tuna fishery poses interesting challenges. The three methods of purse-seining for tuna, log-, school- and dolphin-fishing, catch different mixes of tuna species and sizes, and in addition have different amounts and composition of bycatch. Dolphin sets result in dolphin mortality, but dolphin sets have the least bycatch overall. Log sets have about 30 times the bycatch of school sets by weight per set, which in turn have about 3 times the bycatch of dolphin sets. Most of the bycatch, though, even on dolphin sets, is fish, primarily tuna, marlin, and dorado. These fish have much higher reproductive rates than dolphins, sea turtles, sharks and rays, so the effect of the bycatch is smaller. Although the effects of the fishery on dolphin populations have been strong and are relatively well known, the effects on other marine populations of concern, such as sharks and sea turtles, are mostly unknown.