International Journal of Comparative Psychology, 2007, **20**, 217-227.

Fishery Effects on Dolphins Targeted by Tuna Purse-seiners in the Eastern Tropical Pacific Ocean

Elizabeth F. Edwards
Southwest Fisheries Science Center, U.S.A.

Dolphins in the eastern tropical Pacific Ocean (ETP), particularly spotted (*Stenella attenuata*) and spinner (*Stenella longirostris*) dolphins, are subject to fishery-induced stress due to chase and encirclement by tuna purse-seiners intent on capturing the large yellowfin tuna that are frequently found associated with dolphin schools in this area of the Pacific Ocean. The direct, observed mortality of dolphins in the fishing nets has decreased over the years from several hundred thousand annually during the early 1960's when the fishing practice originated, to less than 5000 dolphins annually (thought to be a biologically insignificant level) since the early 1990s. Despite the decrease in observed mortality, the dolphin populations have not been recovering as expected. In an effort to determine whether fishery-related stress may be contributing to this lack of recovery, through unobserved effects on survival or reproduction, a variety of studies have been and continue to be conducted examining various aspects of interactions between ETP dolphins and the tuna purse-seine fishery. These studies include a review of current knowledge of stress physiology in mammals, a necropsy program to examine dolphins killed during purse-seining operations, a chase-recapture experiment, and various analyses of existing (historical) data which have led to ongoing studies of fishery effects on mother-calf pairs, ETP dolphin reproductive biology, and analyses of dolphin school composition. The effect of noise has not been addressed directly in these studies, but potentially contributes to fishery-related stress in terms of initiating the significant and prolonged evasion response typical of dolphin schools reacting to tuna purse-seiners in the ETP. Although studies completed to date have not provided a definitive answer to whether fishery-induced stress is a significant factor in the lack of dolphin stock recovery in the ETP, it is possible that at least some adults, and probably many young dolphins, are negatively affected by interactions with tuna purse-seine fishing operations.

Dolphins in the eastern tropical Pacific Ocean (ETP), particularly spotted (*Stenella attentuata*) and spinner (*Stenella longirostris*) dolphins, are frequently chased and encircled by tuna purse-seiners intent on capturing the large yellowfin tuna often found associated with dolphin schools in this area of the Pacific Ocean. The set procedure involves using helicopters to search for the disturbances caused by tuna schools feeding in association with dolphins and seabirds (National Research Council, 1992) or for bird flocks over the horizon. Once an associated tuna school has been located and determined large enough to invest the time and effort in capture, the seiner begins to set the net while 4-5 speedboats with large outboard engines are dropped off the back of the vessel to separate dolphins associated with tuna and chase them into the closing purse-seine. In an association unique to the eastern tropical Pacific Ocean (ETP), the tuna remain associated with the dolphins during the chase and capture, so that the closed and pursed seine then contains both the yellowfin tuna and the dolphins. Once the net is entirely closed

I thank Documentes Des Meers for the opportunity to present this work at the Noise Workshop, and the workshop participants and reviewers for numerous valuable discussions and comments. I also thank all the researchers whose work I have reviewed here, for their ongoing efforts to resolve the "tuna-dolphin problem in the ETP". Correspondence concerning this article should be addressed to Elizabeth F. Edwards, Southwest Fisheries Science Center NMFS, 8604 La Jolla Shores Drive, La Jolla, CA, 92037, U.S.A. (Elizabeth.Edwards@noaa.gov).

and pursed at the bottom, a specific maneuver by the vessel ("backdown") creates a long finger of small-mesh net (the "backdown channel") on the side of the seine opposite the vessel. Many dolphins have learned to expect this maneuver (Santurtun & Galindo, 2002) and gather near the appropriate area of the seine, waiting for the channel to form. The dolphins then escape over the submerged far end of the backdown channel and quickly leave the area (Chivers & Scott, 2002).

ETP dolphins respond to an impending set by beginning to flee as soon as the tuna seiner, the helicopter, or the speedboats are perceived (National Research Council, 1992). Because the initial response tends to occur several kilometers from the vessel (Au & Perryman, 1982; Hewett, 1985), initial perception appears to be acoustic rather than visual. The dolphins respond by moving closer together and increasing their swim speed from about 1-2 m/sec to 2-3 m/sec (Chivers & Scott, 2002; i.e., doubling to tripling their previous swim speed and thereby increasing their swimming power requirement by a factor of 8 to 27 times the power required for non-chase swim speeds (Edwards, 2006)).

The chase portion of the set typically lasts 30-40 minutes (with a small percentage of chases lasting up to about 80 minutes), encirclement lasts 30-60 minutes (with a very small percentage of encirclements lasting up to about 75 minutes), and length of confinement lasts another 40-60 minutes (with a small percentage lasting up to about 90 minutes) (Myrick & Perkins, 1995), so that time from initiation of chase to release typically ranges between about 1.5 and 2.5 hours (with a potential maximum in a few sets of about 4 hours). Once the dolphins perceive that the backdown channel is ready, they swim out quickly and continue their escape by swimming at even higher speeds (3-4 m/sec) for about 90 minutes before reverting to pre-chase behaviors (Chivers & Scott, 2002). Thus, each purse-seine set experience may disrupt normal ETP dolphin behavior for at least 30-40 minutes, if the dolphin manages to escape prior to capture, and for 3-4 hours (occasionally up to 5.5 hours) if the dolphin is captured in the seine and then released.

During the early 1960s, when the seining practice originated, several hundred thousand dolphins died in tuna purse-seine nets each year, reducing the populations spotted and spinner dolphins in the ETP by 70-80% (Wade, 1994). Improvements in fishing practices and introduction of individual vessel mortality limits, as well as apparent learning by the dolphins (currently, only about 4% of encircled dolphins need assistance leaving the net during backdown (Santurtun & Galindo, 2002)), have drastically reduced dolphin deaths in tuna nets, to less than 5000 dolphins annually (thought to be a biologically insignificant level) since the early 1990s (Inter-American Tropical Tuna Commission, 2004).

However, despite this dramatic decrease in purse-seine mortality, at least two stocks, northeastern offshore spotted and spinner dolphins, have not been recovering as expected (Gerrodette & Forcada, 2005). Because fishing effort on dolphins remains high (10,000-14,000 purse-seine sets per year (Inter-American Tropical Tuna Commission, 2004)), with each spotted dolphin being chased about 11 times and captured about 3 times per year, on average (Reilly et al., 2005), it is hypothesized that indirect effects of the fishery may adversely impact ETP dolphins. This potential for ongoing adverse fishery interactions has led to a variety of research projects addressing the possibility that fishery effects (interactions) may be contributing to the lack of population recovery through unobserved effects on dolphin survival or reproduction.

Although the issue of adverse fishery effects (in addition to direct mortality) on ETP dolphins has been of concern since the early days of the fishery (e.g., Stuntz & Shay, 1979; Cowan & Walker, 1979; Coe & Stuntz, 1980) research through the early 1990's focused primarily on reducing directly-observed mortality in the purse-seines. Once the current low level of purse-seine mortality had been achieved, research focus turned to investigating other types of fishery effects.

A major series of research projects was initiated between 1997 and 2002, in accord with mandates of the International Dolphin Conservation Program Act (IDCPA), an amendment to the US Marine Mammal Protection Act (MMPA) (Reilly et al., 2005). IDCPA-mandated fishery effects studies focused on the question "is the fishery having a significant adverse impact on ETP dolphins?" and included four related projects broadly characterized as stress studies. These included 1) a review of current knowledge of stress physiology in mammals, with emphasis on marine mammal physiology, 2) a necropsy program to examine dolphins killed during purse-seining operations, 3) a chase-recapture experiment *in situ* using a chartered purse-seine vessel, and 4) various analyses of existing (historical) data (Reilly et al., 2005). The effect of related noise was not specifically investigated as a stressor in these studies, but contributes to fishery-related stress in terms of initiating the significant and prolonged evasion responses typical of dolphin schools chased and encircled by tuna purse-seiners in the ETP (Au & Perryman, 1982; Hewitt, 1985; Chivers & Scott, 2002). The IDCPA research program also included a suite of studies to estimate current abundances, monitor environmental associations and their potential effects, and assess status and trends of these dolphin populations. Results of those studies are not covered here.

This paper summarizes results from completed studies and presents status reports for ongoing and proposed studies addressing the question of whether fishery interactions may be negatively affecting population recovery of ETP dolphins.

Completed Studies

Research Prior to the IDCPA Program

Limited data were collected prior to the IDCPA program, although the potential for fishery-related stress was recognized early in the fishery, primarily based on observations of passive-sinking behaviors by dolphins in the purse-seine nets (Coe & Stunz, 1980). These unusual behaviors suggested the possibility of "capture myopathy" (a degenerative muscle condition which can lead to delayed death, thus creating unobserved fishery-related mortality; Stunz & Shay, 1979). Subsequent examination and sampling of *Longissimus dorsi* and hypaxial muscle from 65 dolphins killed in ETP tuna purse-seines found "no evidence of myopathy" (Cowan & Walker, 1979), but this sample size is too small to definitively eliminate the possibility of capture myopathy affecting ETP dolphins at the population level. Another study suggested that examination of adrenal glands might provide a measure of fishery-related stress (Myrick & Perkins, 1995).

IDCPA Program Research

The stress literature review summarized current knowledge about the effects of physiological and behavioral stress in mammals, and related that information to potential effects on dolphins chased and encircled by tuna purse-seiners (Curry, 1999; St. Aubin, 2002a). The review concluded that tuna purse-seine fishing activities entail well-recognized stressors in other mammals, especially wild animals, including prolonged heavy exertion, social disturbance, and disruption of normal activities such as foraging. Typical mammalian responses to such disturbances include changes in metabolism, growth, reproduction, and immune status, any of which, alone or in combination, could significantly affect survival and reproduction. Of particular concern for ETP dolphins was the observation that prolonged heavy exertion in other wild mammals can lead to capture myopathy. Although specific response levels to specific stressors differ in detail between different mammals and environments, the review found that in general, the types of stressors presented by tuna purse-seine activities may affect dolphin survival, but quantitative estimates of the magnitude of these effects are not available (Curry, 1999; Reilly et al., 2005).

The necropsy study examined various physical characteristics of dolphins accidentally killed during tuna purse-seine operations. Due to logistic difficulties, only 56 dolphins were sampled during the 3-year study, far fewer than the desired minimum (for statistical power) of 300 dolphins per stock. However, although the small sample size precluded population-level conclusions, results provided revealing snapshots of physiological conditions and characteristics of dolphins killed in the nets. Various diseases unrelated to the fishery, but characteristic of normally healthy populations of wild mammals, were found in the majority of the dolphins (Cowan & Curry, 2002). Lymph nodes indicated normal, active lymphoid systems (Romano, Abella, Cowan, & Curry, 2002a). Heart, lungs and kidney contained lesions directly linked to death by asphyxiation, possibly resulting from an overwhelming alarm reaction leading to death by cardiac arrest (Cowan & Curry, 2002). Tissue abnormalities presenting as patchy fibrous scars in heart muscle and associated blood vessels may have formed previously in response to excess secretion of stress hormones, possibly indicating prior stress responses (e.g., possibly to fishery activity or predation attempts), although the direct cause and physiological consequences of the lesions could not be determined (Cowan & Curry, 2002). Opportunistic samples of skeletal muscle showed cell damage similar to that in heart muscle, indicative of a degree of capture myopathy that could lead to unobserved mortality in some cases (Reilly et al., 2005).

The Chase Encirclement Stress Study (CHESS) examined physiological and behavioral responses of ETP dolphins to repeated chase and encirclement (Forney, St. Aubin, & Chivers, 2002). During a two-month period, schools of spotted and mixed spotted/spinner dolphins were located, chased and encircled by a chartered tuna purse-seine vessel using fishery-typical techniques (Forney et al., 2002). Individual dolphins were sampled, tagged and subsequently released with the rest of the captured dolphins. Radio-tagged focal dolphins were followed by a NOAA research vessel, and attempts were made over the following days to recapture the focal dolphin(s) and any associates. CHESS studies included analyses of blood parameters (standard veterinary blood panels, with particular focus on exertion-related enzymes and stress hormones), immune function, thermal condition, behavior, and reproductive parameters, with the intention of determining serial changes through time with repeated recaptures. Initial (first capture) samples were collected from several dozen dolphins, but recaptures were limited because tagged dolphins generally separated from their original school rather than remaining associated. Blood was obtained from 61 dolphins, 53 of which were assumed to be first captures; the remaining 8 samples were collected from dolphins recaptured 1-3 times. In general, these limited sample sizes precluded drawing population-level conclusions about effects of chase and capture. However, a number of important observations relevant to the basic objective were made, and these are summarized below.

Immune function was normal in all blood samples, with no notable abnormalities in the captured or recaptured dolphins (Romano, Keogh, & Danil, 2002b). Hormone and enzyme analyses provided strong evidence for activation of an acute stress response and muscle injury due to exertion (St. Aubin, 2002b). Samples from animals chased for 20-30 minutes exhibited mild muscle damage (consistent with lesions observed in the Necrospy Study samples) (St. Aubin, 2002b). Blood changes were not sufficient to cause life-threatening capture myopathy in any of the animals examined, but individuals differed greatly in overall stress response (St. Aubin, 2002b). Some dolphins showed much more dramatic elevations in hormones, enzymes, and other metabolic indicators, implying a wide variety of responses in the natural population (St. Aubin, 2002b).

The potential for heat stress, particularly in pregnant females required to maintain blood flow to the uterus, placenta and fetus regardless of body temperature, was evaluated by examining thermal photographs of skin surface temperatures after chases of more than 75 minutes (Pabst, McLellan, Meagher, & Westgate, 2002). Heat flux increased during chase for one of two tagged individuals, but core body temperatures were stable for all but one of 48 sampled dolphins, indicating that ETP dolphins are able to regulate body temperature despite elevated swim speeds during chase.

As observed in previous studies (e.g., Scott & Cattanach, 1998), dolphin school dynamics were highly fluid so that associations of individual dolphins were quite variable (Chivers & Scott, 2002). The passive-sinking behavior seen during the 1970s (Coe & Stunz, 1980) was not evident, although rafting behavior (vertical position with head out of the water) still occurred in some dolphins (0 to 8.5 % of the individuals in the net) at some times prior to backdown (Santurtun & Galindo, 2002). In 77% of sets, dolphins were observed circling outside the purse-seine, and overall, it was evident that ETP dolphins are now familiar with the purse-seine procedure and can anticipate backdown for release from the net (Santurtun & Galindo, 2002).

With extremely limited data, it was impossible to determine any effect of capture or recapture on reproduction. No fetal loss was observed, although there were modest decreases in levels of progesterone and testosterone in the two animals analyzed after successive recaptures (St. Aubin, 2002b). Nine females with relatively large calves were captured during at least one set. Three females originally captured with relatively large calves were recaptured with the same calf in subsequent sets, including one pair chased seven times and recaptured four times, and two pairs chased and captured twice. These recaptures indicate that larger calves are capable of remaining associated with their mothers during sets. However, developmental issues indicate that smaller calves (less than 1 year postpartum) may have more difficulty remaining associated with the mother during fishery activities (Noren, Biedenbach, & Edwards 2006; Noren & Edwards, 2007; Noren, Biedenbach, Redfern & Edwards 2007).

Historical biological data were examined in a number of ways, including: 1) to determine whether dolphin behavior differs relative to level of recent fishing effort (Mesnick, Archer, Allen, & Dizon, 2002); 2) to compare the demographic and reproductive parameters of spinner dolphins schools in 1988-1993 vs. 1998-2000 based on aerial photographs taken during NMFS research cruises (Cramer & Perryman, 2002); 3) to estimate the energetic cost to dolphins of purse-seine set evasion (Edwards, 2002); 4) as contributing data for a review of all available information on physiological and behavioral development in dolphin calves (Noren & Edwards, 2007); and 5) to compare the number of lactating females versus the number of nursing calves killed in the same sets (Archer, Gerrodette, Chivers, & Jackson, 2001; Archer, Gerrodette, Chivers, & Jackson, 2004). The results of the latter studies have led to the current focus on fishery effects on ETP dolphin mother-calf pairs and reproductive biology.

Mesnick, Archer, Allen, & Dizon (2002) found that spotted and spinner dolphins (the target species) exhibited more ship evasion and avoidance than did non-targeted dolphin stocks in areas with greater fishing effort. Chivers & Scott (2002) found that escape from tuna purse-seine sets involves prolonged and high-speed swimming (at least 90 minutes at 3-4 m/sec) in addition to the typical 60-100 minutes involved in chase and encirclement (Myrick & Perkins, 1995), bringing the total time of typical set involvement to 3-4 hours, including 2-3 hours of elevated swim speeds. Cramer & Perryman (2002) found that the proportion of calves in schools was not related to the species composition or number of conspecifics in the school, but was significantly lower in more recent years compared to earlier years. Edwards (2002) found that that additional energy costs of evading purse-seine sets are probably not important for adult ETP dolphins, but may present a significant burden to small nursing calves (and potentially their mothers). Archer et al. (2001) found far fewer calves than expected from the number of lactating females killed in tuna purse-seine nets, suggesting that at least some of the calves become separated from their mothers during tuna purse-seine sets in the ETP and that subsequent unobserved calf mortality is a potentially important issue. Noren & Edwards (2007) found that physical limitations of small dolphin calves coupled with behavioral independence of mothers may cause mother-calf separation during tuna purse-seine set evasion, particularly with calves less than a year postpartum.

Despite limited sample sizes, IDCPA studies identified a number of fishery-related effects on ETP dolphins that could be contributing to stress-related injury and/or unobserved mortality (Reilly et al., 2005). These include 1) moderately elevated stress hormones (catecholemines) and enzymes in live-captured dolphins, indicative of muscle damage; 2) evidence of past (healed) muscle and heart damage in necropsy specimens (dolphins killed in the fishery), 3) fatal heart damage in virtually all necropsy specimens, possibly related to elevated catecholamines, 4) prolonged response to set activities, including post-release as well as during chase and capture, and 5) separation of mothers and calves. Although the effects observed in live-captured animals were all sub-lethal, differences in individual reactions to stressors could lead to more critical responses in some animals compared to others (St. Aubin, 2002b).

Research Subsequent to the IDCPA Program

Following discovery of the significant discrepancy between mortality of lactating females and nursing calves (Archer et al., 2001), additional research quantified the “calf deficit”, determining that 75-95% of lactating females killed in tuna purse-seine sets are killed without an accompanying calf (Archer et al., 2004). Given the importance of the mother-calf bond to calf survival, and the potential for mating failure, fetal resorption or abortion in response to fishery activities, research subsequent to the IDCPA has focused on effects that fishery interactions may have on ETP dolphin mother-calf pairs, reproduction and calf survival.

Mother-calf research has focused on factors that can be expected to affect the proximity of mothers and calves during attempted evasion of purse-seine sets, with particular emphasis on the swimming behavior known as drafting in echelon position whereby the calf positions itself slightly above and behind the mother’s midsection (Norris & Prescott, 1961). Mathematical and aerodynamic modeling of movement forces (Weihs, 2004; Weihs, Ringel, & Victor, 2006) and empirical kinematic analyses of swimming motions of bottlenose dolphin mothers and calves from birth through two years postpartum (Noren et al., 2006, Noren et al., 2007) both confirmed and quantified the significant hydrodynamic advantages (decreased cost of swimming and/or increased velocity) enjoyed by dolphin calves swimming in echelon, as well as the hydrodynamic disadvantages (decreased swim performance and increased swim effort) suffered by dolphin mothers (Noren, 2007). Mother dolphins swimming in echelon swim only about half as fast at mothers swimming independently (Noren, 2007), while 0-1 month calves in swimming echelon experience a 28% increase in average swim speed, 22% reduction in fluke stoke amplitude, and 19% increase in distance per stoke compared to calves swimming independently (Noren et al., 2007). Neonate dolphin calves can gain up to 90% of the thrust needed to move through the water alongside the mother at speeds up to 2.4 m/sec (Weihs, 2004), while mean and maximum swim speeds of 0-1 month old calves swimming independently were only 37% and 52% of adult speeds, with adult levels not achieved until at least one year postpartum (Noren et al., 2006). Stroke amplitude and distance covered per stroke were also significantly lower than adult levels for independently swimming calves during the first year postpartum. Lower size-specific swim speed in 0-3 month olds compared to calves older than 10 months indicated that factors other than size (e.g., underdeveloped physiology) act synergistically with small body size to limit independent swim performance in dolphins during ontogeny (Noren et al., 2006). The modeling studies also revealed the importance of precise positioning for effective drafting, and included an observation of disrupted drafting when a neonate calf lost coordination during a respiratory leap attempted during escape-speed swimming in the ETP (Weihs, 2004). The importance of drafting for remaining associated with adults is illustrated by energetics modeling of swim speed duration capacity of independently-swimming (non-drafting) ETP spotted dolphins. Neonate spotted dolphins require 3.6 times more power per kilogram of muscle than an adult, to swim the same speed, and have a burst maximum speed of about 3 m/sec compared to an adult’s 6 m/sec (Edwards, 2006). Even at two years of age, spotted dolphin calves must produce about 40% more power per kilogram of muscle than an adult to swim a given speed. Loss of the drafting advantage due to high-speed, fast maneuvering swimming during evasion of tuna purse-seine sets appears to be a significant and plausible source for the observed calf deficit.

Ongoing swimming kinematics research, not yet completed, includes estimation of the cost to mother dolphins of swimming with near-term pregnant morphology. Future modeling work should include estimation of the limits to drafting by dolphin calves in terms of speed and maneuvering during evasion of tuna purse-seine sets. Ongoing research on reproduction and survival includes development and application of methods to determine pregnancy rates of ETP dolphins from progesterone analyses of blubber biopsies taken *in situ*, and estimation of fetal mortality rates in ETP dolphins, based on biological samples collected during the 1980s from fishery-killed specimens.

Conclusion

In general, studies of fishery effects on ETP dolphin physiology, behavior, and population dynamics indicate that adult dolphins chased, encircled, and released during tuna purse-seine sets experience acute, intense stress during the event but most appear to recover from this experience, though some may develop long-term sequelae such as vascular and muscle lesions, reproductive failure, or reduced survival. Because even a relatively small fishery-induced decrease in reproduction or survival could lead to the observed failure of population recovery for ETP dolphins (e.g., Gerrodette & Forcada, 2005), it is possible that fishery effects on adults remain an important factor in the observed lack of population recovery The estimated calf deficit suggests that the purse-seine fishing procedure may be disrupting mother-calf associations in the ETP, and the studies of calf physiology, behavior, and swimming characteristics suggest that nursing calves not reunited with their mothers are not likely to survive. Incorporating age-based likelihoods of calf separation and subsequent mortality into population dynamics models that include age-specific fishery encounter rates is being investigated as a tool to evaluate these potential effects of fishery activity on calf survival and subsequent population dynamics.

References

Archer, F., Gerrodette, T., Chivers, S., & Jackson, A. (2004). Annual estimates of the unobserved kill of pantropical spotted dolphin (*Stenella attenuata*) calves in the tuna purse-seine fishery in the eastern tropical Pacific. *Fishery Bulletin*, **102**(2), 233-244.

Archer, F., & Robertson, K. M. (2004). Age and length at weaning and development of diet of pantropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. *Marine Mammal Science*, **20**(2), 232-245.

Archer, F., Gerrodette, T., Dizon, A., Abella, K., & Southern, S. (2001). Unobserved kill of nursing dolphin calves in a tuna purse-seine fishery. *Marine Mammal Science*, **17**, 540-554.

Au, D., & Perryman, W. (1982). Movement and speed of dolphin schools responding to an approaching ship. *Fishery Bulletin*, **80**(2), 371-379.

Chivers, S. J., & Scott, M. D. (2002). Tagging and tracking of *Stenella spp*. during the 2001 Chase Encirclement Stress Studies Cruise. *Administrative Report LJ-02-11*, NMFS, Southwest Fisheries Science Center, La Jolla, CA..

Coe, J. M., & Stuntz, W. (1980). Passive Behavior by the Spotted Dolphin, *Stenella attenuata*, in Tuna Purse Seine Nets. *Fishery Bulletin*, **78**(2), 535-537.

Cowan, D. F., & Curry, B. E. (2002). Histopathological assessment of dolphins necropsied onboard vessels in the eastern tropical Pacific tuna fishery. *Administrative Report LJ-02-24C,* NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Cowan, D., & Walker, W. A. (1979). Disease Factors in *Stenella attenuata* and *Stenella longirostris* Taken in the Eastern Tropical Pacific Yellowfin Tuna Purse Seine Fishery. *Administrative Report LJ-79-32C*, NMFS, Southwest Fisheries Science Center, La Jolla, CA..

Cramer, K.., & Perryman, W. L. (2002). Estimation of reproductive and demographic parameters of the eastern spinner dolphin (*Stenella longirostris orientalis*) using aerial photography. *Administrative Report LJ-02-31*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Curry, B. (1999). Stress in mammals: the potential influence of fishery-induced stress on dolphins in the eastern tropical Pacific Ocean. *NOAA-TM-NMFS-SWFSC-261*.

Edwards, E. F. (2006). Duration of unassisted swimming activity for spotted dolphin (*Stenella attenuata*) calves: Implications for mother-calf separation during tuna purse-seine sets. *Fishery Bulletin*, **104**, 125-135.

Edwards, E. F. (2002). Energetics consequences of chase by tuna purse-seiners for spotted dolphins (*Stenella attenuata*) in the eastern tropical Pacific Ocean. *Administrative Report LJ-02-29*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Forney, K.A., St. Aubin, D. J., & Chivers, S. (2002). Chase Encirclement Stress Studies on dolphins involved in eastern tropical Pacific Ocean purse-seine operations during 2001. *Administrative Report LJ-02-32*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Gerrodette, T., & Forcada, J. (2005). Non-recovery of two spotted and spinner dolphin populations in the eastern tropical Pacific Ocean. *Marine Ecology Progress Series*, **291**, 1-21.

Hewitt, R.P. (1985). Reaction of dolphins to a survey vessel: Effects on census data. *Fishery Bulletin*, **83**(2), 187-193.

Inter-American Tropical Tuna Commission. (2004). *Inter-American Tropical Tuna Commission Annual Report 2004.* Inter-American Tropical Tuna Commission, La Jolla, CA.

Mesnick, S.L., Archer, F., Allen, A. C., & Dizon, A. E. (2002). Evasive behavior of eastern Pacific dolphins relative to effort by the tuna purse-seine fishery. *Administrative Report LJ-02-30*, NMFS, Southwest Fisheries Science Center, La Jolla, CA 92037.

Myrick, A. C., & Perkins, P. C. (1995). Adrenocortical color darkness as indicators of continuous premortem stress in chased and purse-seined male dolphins. *Pathophysiology*, **2**, 91-204.

Noren, S. R. (2007). Infant Carrying Behaviour in Dolphins: Costly parental care in an aquatic environment. *Functional Ecology*, **22**, *284-288.*

Noren, S. R., Biedenbach, G., Redfern, J. V., & Edwards, E. F. (2007). Hitching a ride: The formation locomotion strategy of dolphin calves. *Functional Ecology*, **22**, *278-283.*

Noren, S. R., & Edwards, E. F. (2007). Physiological and behavioral development in delphinid calves: Implications for calf separation and mortality due to tuna purse-seine sets. *Marine Mammal Science*, **23**(1), 15-29.

Noren, S. R., Biedenbach, G., & Edwards, E. F. (2006). Ontogeny of swim performance and mechanics in bottlenose dolphins (*Tursiops truncatus). Journal of Experimental Biology*, **209**, 4724-4731.

Norris, K. S., & Prescott, J. S. (1961). Observations on Pacific Cetaceans of Californian and Mexican Waters. *University of California Publications in Zoology*, **63**, 291-402.

National Research Council. (1992). Dolphins and the tuna industry/Committee on reducing porpoise mortality from tuna fishing. *National Academy Press.* Washington, DC.

Pabst, D.A., McLellan, W. A., Meagher, E. M., & Westgate, A. J. (2002). Measuring temperatures and heat flux from dolphins in the eastern tropical Pacific: Is thermal stress associated with chase and capture in the ETP tuna purse-seine fishery? *Administrative Report LJ-02-34C*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Romano, T., Abella, K., Cowan, D., & Curry, B. (2002a). Investigation of the morphology and autonomic innervation of the lymphoid organs in the pantropical spotted, spinner, and common dolphins (*Stenella attenuata, Stenella longirostris,* and *Delphinus delphis*) incidentally entangled and asphyxiated in the tuna purse-seine fishery in the eastern tropical Pacific. *Administrative Report LJ-02-25C*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Romano, T., Keogh, M., & Danil, K. (2002b). Investigation of the effects of repeated chase and encirclement on the immune system of spotted dolphins (*Stenella attenuata*) in the eastern tropical Pacific. *Administrative Report LJ-02-35C*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Reilly, S. B., Donahue, M. A., Gerrodette, T., Forney, K., Wade, P., Ballance, L., Forcada, J., Fiedler, P., Dizon, A., Perryman, W., Archer, F., & Edwards, E. F. (2005). Report of the Scientific Research Program under the International Dolphin Conservation Program Act. *NOAA Technical Memorandum* NMFS, NOAA-TM-NMFS-SWFSC-372.

Santurtun, E., & Galindo, F. (2002). Coping behaviors of spotted dolphins during fishing sets. *Administrative Report LJ-02-36C*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Scott, M., & Catanach, K. (1998). Diel patterns in aggregations of pelagic dolphins and tunas in the eastern Pacific. *Marine Mammal Science*, **14**(3), 401-428.

St. Aubin, D. J. (2002a). Further assessment of the potential for fishery-induced stress on dolphins in the eastern tropical Pacific. *Administrative Report LJ-02-23C*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

St. Aubin, D. J. (2002b). Hematological and serum chemical constituents in pantropical spotted dolphins (*Stenella attenuata*) following chase and encirclement. *Administrative Report LJ-02-37C*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Stuntz, W. L., & Shay, T. B. (1979). Report on Capture Stress Workshop. *Administrative Report LJ-79-28*, NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Wade, P. R. (1994). Abundance and Population Dynamics of Two Eastern Pacific Dolphins, *Stenella attenuata* and *Stenella longirostris orientalis*. (Ph. D. Dissertation, University of California, San Diego) .

Weihs, D., Ringel, M., & Victor M. (2006). Aerodynamic Interactions Between Adjacent Slender Bodies. *AIAA Journal*, **44**(3), 481-484.

Weihs, D. (2004). The Hydrodynamics of Dolphin Drafting. *Journal of Biology*, **3**(2)**,** 801-815.