INTERNATIONAL DOLPHIN CONSERVATION PROGRAM

SCIENTIFIC ADVISORY BOARD

6TH MEETING

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REVIEW OF DOLPHIN RESEARCH, 2002-2008, AND PLAN OF WORK

In 2002, the U.S. National Marine Fisheries Service (NMFS) completed a Report to the U.S. Congress of Scientific Research Program as mandated by the International Dolphin Conservation Program Act. This report summarized its research to determine whether the tuna purse-seine fishery was having a "significant adverse impact" on spotted and spinner dolphin populations, and thus determine whether the U.S. definition of "dolphin-safe" tuna would be changed to correspond with the definition under the AIDCP. The IATTC staff wrote a Report to the Secretary of Commerce that disagreed with many of the opinions expressed in the NMFS Report. Dr. William Hogarth, who had been designated by the Secretary to make the "significant adverse impact" decision, made a Final Finding that the fishery was not having an adverse impact on dolphin populations in the eastern tropical Pacific (ETP). In 2004, the Final Finding was overturned by the U.S. District Court, arguing in its Summary Judgment that its reading of the NMFS Report suggested that a "significant adverse impact" was occurring, that the studies mandated by Congress had not been completed, and that the U.S. definition of "dolphin-safe" tuna should not change.

Many of the scientific issues raised by the NMFS and IATTC Reports, such as abundance estimates and populations trends, the effect of fishery-induced stress on dolphins, mother-calf separation leading to calf mortality, and unreported mortalities, have been part of the Work Plan of the Scientific Advisory Board (SAB) since its inception. The current Work Plan (Appendix A) is to be reviewed at the 6th meeting of the SAB.

In an expansion of the normal summary of the SAB's Work Plan, this document will briefly describe research published in the five years since the 2002 Final Finding, in addition to the ongoing research in each area.

A. REVIEW OF RESEARCH

1. Prevalence and significance of cow-calf separation

The NMFS Report cited a study by Archer *et al*. (2001) that discovered that some dolphin calves were being orphaned as a result of fishery mortality and this could subsequently result in mortalities to these calves that would not be observable. They calculated that mortality could be underestimated by 10-15% for spotted dolphins and 6-10% for spinner dolphins. The IATTC Report calculated an additional potential annual mortality of less than 120 due to this cause. While there was no evidence that mothers abandoned their calves prior to a set, and some evidence against it, it was speculated that mothers and calves might become separated[1] during the chase, that calf mortality might result, and that this unobserved mortality might be responsible for the difference between the observed annual population growth rates of 1.7% for spotted dolphins and 1.4% for spinner dolphins and the 4% growth rate the NMFS Report's authors expected to observe.

Since 2002, this has been a particularly active area of research. Studies have examined the spatial relationship between mothers and newborn calves, and the potential energetic costs to a mother of swimming in close association with a calf (Weihs 2004; Edwards 2006; Noren *et al*. 2006; 2008; Weihs *et*

[1] Dolphin calves typically swim in their mother's slipstream, allowing the calf to keep pace with relatively little effort. If the calf falls out of this "drafting" position, it is argued, there is a possibility that it could no longer keep up with the mother unless the mother slows down.

al. 2006; Noren and Edwards 2007; Noren 2008). These studies indicate that newborn calves (less than a month old) would be the most vulnerable to separation from their mother, and calves less than a year old would be at risk. The crucial question of "Would a mother abandon its calf during a chase?" still remains unanswered, however.

Ongoing research by the NMFS has expanded this topic to examine potential fetal mortality caused by fishery operations.

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.
http://fishbull.noaa.gov/1041/edwards.pdf

S. R. Noren. 2008. Infant carrying behaviour in dolphins: Costly parental care in an aquatic environment. Functional Ecology 22(2):284–288.
http://www.blackwell-synergy.com/doi/full/10.1111/j.1365-2435.2007.01354.x

Noren, S.R., G. Biedenbach, and E.F. Edwards. 2006. Ontogeny of swim performance and mechanics in bottlenose dolphins (*Tursiops truncatus*). Journal of Experimental Biology 209:4724-4731.
http://jeb.biologists.org/cgi/content/full/209/23/4724

Noren, S.R. and E.F. Edwards. 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.
http://www.blackwell-synergy.com/doi/pdf/10.1111/j.1748-7692.2006.00083.x

S. R. Noren, G. Biedenbach, J. V. Redfern, E. F. Edwards. 2008. Hitching a ride: the formation locomotion strategy of dolphin calves. Functional Ecology 22(2):278–283.
http://www.blackwell-synergy.com/doi/abs/10.1111/j.1365-2435.2007.01353.x

Weihs, D. 2004. Hydrodynamic of dolphin drafting. J. Biology 3:1-23. http://jbiol.com/content/3/2/8

Weihs, D., M. Ringel, and M. Victor. 2006. Aerodynamic interactions between adjacent slender bodies. AIAA Journal 44(3):481-484.
http://intl.ieeexplore.ieee.org/iel5/4380867/4380868/04380899.pdf?tp=&isnumber=4380868&arnumber=4380899

2. Life history and fishery-related stress effects studies

The NMFS Report found that there was no or inconclusive evidence that stress was having a significant adverse impact on dolphin populations, although the sample sizes collected for these studies were low.

Since 2002, four papers on dolphin life history have been published (Archer and Robertson 2004; Perrin *et al*. 2005; Danil and Chivers 2006, 2007) and two papers on dolphin reproduction are under review (Cramer *et al*. in review; Larese and Chivers in review). NMFS has also developed a method to diagnose reproductive status of ETP dolphins from the blubber attached to most skin biopsy samples (Kellar *et al*. 2006, in review); this information is being used to estimate pregnancy rates for dolphin stocks. The IATTC staff has now computerized all its historical data recorded by observers on the Dolphin Life History forms. A study of the movements and diving behavior of spotted dolphins has been completed (Scott and Chivers in press).

The SAB recommended reinstating a dolphin life-history sampling program by observers to look at trends in vital rates. Funding has not yet been obtained to collect new samples from dolphins taken in the fishery, however.

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

http://www.blackwell-synergy.com/doi/abs/10.1111/j.1748-7692.2004.tb01153.x

Cramer, K. W. Perryman, and T. Gerrodette. In review. Declines in reproductive indices in two depleted dolphin populations in the eastern tropical Pacific.

Danil, K. and S.J. Chivers. 2006. Habitat-based spatial and temporal variability in life history characteristics of female common dolphins *Delphinus delphis* in the eastern tropical Pacific. Marine Ecology Progress Series 318:277-286.
http://www.int-res.com/articles/meps2006/318/m318p277.pdf

Danil, K. and S.J. Chivers. 2007. Growth and reproduction of female short-beaked common dolphins, *Delphinus delphis*, in the eastern tropical Pacific. Canadian Journal of Zoology 85:108-121.
http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?_handler_=HandleInitialGet&journal=cjz&volume=85&calyLang=eng&articleFile=z06-188.pdf

Kellar, N.M., M.L. Trego, C.I. Marks, S. Chivers, K. Danil, and F.E. Archer. In review. Blubber testosterone: A marker of male reproductive status for cetacean biopsy samples.

Kellar, N.M., M.L. Trego, C.I. Marks, and A.E. Dizon. 2006. Determining pregnancy from blubber in three species of delphinids. Marine Mammal Science 22:1-16.
http://www.blackwell-synergy.com/doi/full/10.1111/j.1748-7692.2006.00001.x?prevSearch=authorsfield%3A%28trego%29

Larese, J.P. and S.J. Chivers. In review. Growth and reproduction of female eastern and whitebelly spinner dolphins (*Stenella longirostris*) incidentally killed in the eastern tropical Pacific tuna purse-seine fishery.

Perrin, W.F., M.L.L. Dolar, S.J. Chivers, and C.M. Chan. 2005. Length-weight relationships in the spinner dolphin (*Stenella longirostris*). Marine Mammal Science 21(4):765-778.
http://www.blackwell-synergy.com/doi/pdf/10.1111/j.1748-7692.2005.tb01264.x

Scott, M.D., and S.J. Chivers. In press. Movements and diving behavior of pelagic spotted dolphins. Marine Mammal Science.

3. Review of currently available estimates of abundance for dolphin stocks

The NMFS Report presented 1998-2000 average population estimates of 641,153 (CV = 16.9%) for northeastern spotted dolphins and 448,608 (CV = 22.9%) for eastern spinner dolphins, with corresponding population growth rates of 1.7% and 1.4%. These results were interpreted as a failure to recover because the growth rates were not significantly different from zero and because it was expected that a depleted stock would increase at the maximum rate possible, a rate assumed to be 4% (see also Gerrodette and Forcada 2005).

NMFS conducted cruises in 2003 and 2006 to obtain data for new estimates of abundance for dolphin populations, particularly for the northeastern spotted and eastern spinner dolphins (Gerrodette *et al*. 2008). The NMFS also conducted a cruise in 2007 to test line-transect assumptions. The 2006 estimate for northeastern spotted dolphins was 857,884 (CV = 22.5%) and the estimate for eastern spinner dolphins was 1,062,879 (CV = 25.7%). The authors suggest that these populations may be beginning to recover. The exponential rate of change (r) for northeastern spotted dolphins was 1.0% during 1986-2006 but higher, 3.5%, during the more recent years, 1998-2006. The rate for eastern spinner dolphins was 1.9% during 1986-2006 but was much higher, 9.2%, during 1998-2006. The authors noted that the confidence interval included zero, but it also includes the NMFS expected value of 4% as well. Possibly coupled with the increase in northeastern spotted dolphins was an apparent decrease in the western/southern spotted dolphin population of 2.3% during 1986-2006 and -8.0% during 1998-2006. This suggests the possibility that shifts across the stock boundary lines (at 5°N latitude and 120°W longitude) may have occurred for the spotted dolphin.

The SAB considered a recommendation at its 4th meeting from the Technical Workshop on Calculating N_{min} on how to incorporate more-recent population estimates of dolphin stocks into the estimates of N_{min} that are used to calculate stock mortality limits. The SAB agreed that the logistic population model used by the Technical Workshop was appropriate, but that it was premature to recommend its adoption for the calculation of stock mortality limits. The IATTC staff will be updating logistic and age-structured models to incorporate the most recent information from the NMFS surveys.

Gerrodette, T. and J. Forcada. 2005. Non-recovery of two spotted and spinner dolphin populations in the eastern tropical Pacific Ocean. Marine Ecology Progress Series 291:1-21.
http://swfsc.noaa.gov/uploadedFiles/Research/Legal_Mandates/International_Dolphin_Conservation_Program_Act_(IDCPA)/GerrodetteandForcada2005MEPS.pdf

Gerrodette, T., G. Watters, W. Perryman, and L. Ballance. 2008. Estimates of 2006 dolphin abundance in the eastern tropical Pacific, with revised estimates from 1986-2003. NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFSC-422. 39 pp.

http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-422.pdf

Wade, P.R., G.M. Watters, T. Gerrodette, and S.B. Reilly. 2007. Depletion of spotted and eastern spinner dolphins in the eastern tropical Pacific: Modeling hypotheses for their lack of recovery. Marine Ecology Progress Series 343:1-14.
http://www.int-res.com/articles/feature/m343p001.pdf

4. Stock assessment of coastal spotted dolphins

The NMFS Report noted the abundance estimate for the coastal spotted dolphins was 143,725 (CV = 35.7%), but concluded that its status could not be determined due to the lack of historical abundance and mortality estimates.

Recent genetics work suggests there may be more stocks of coastal spotted dolphins than the single one currently recognized (Escorza-Trevino *et al*. 2005; Rosales 2006). The Gerrodette *et al*. (2008) abundance estimate for 2006 was 278,155 coastal spotted dolphins (CV = 59.0%); the exponential rate of change (r) for this population was 30.7% during 1986-2006 and 7.7% during 1998-2006. Because these high growth rates are biologically improbable, it is more likely that the early estimates were artificially low because the surveys were focussed on estimating abundances of northeastern spotted dolphin and eastern spinner dolphins and were not designed to adequately cover the coastal areas. An AIDCP-sponsored coastal ecosystem survey designed to get accurate estimates of coastal spotted dolphins was planned for 2007, but was postponed due to lack of funding. The U.S. plans to work closely with the other AIDCP Parties to coordinate this cruise for a future year.

Escorza-Trevino, S., F.I. Archer, M. Rosales, A. Lang, and A.E. Dizon. 2005. Genetic differentiation and intraspecific structure of eastern tropical Pacific spotted dolphins, *Stenella attenuata*, revealed by DNA analyses. Conservation Genetics 6:587-600.

Rosales, M. 2006. Population structure of coastal spotted dolphins, *Stenella attenuata*, in the eastern tropical Pacific. M.S. Thesis, California State University, Los Angeles.

5. Ecosystem effects

To explain why some dolphin populations were not increasing at the rate NMFS expected (4%), the NMFS examined whether a change in the carrying capacity of the ecosystem could have occurred. The NMFS Report concluded that a such a change in the ecosystem was not likely, although there were significant increases in biomass during 1986-2000 for other ETP species, such as pilot whales, Bryde's whales, common dolphins, and yellowfin tuna. Also, a NMFS Expert Panel on the Ecosystem agreed that ecosystem variation could have a significant impact on dolphin populations in the eastern Pacific Ocean.

A series of papers were published on the oceanography of the eastern Pacific (Fiedler and Lavin 2006;

Redfern *et al*. 2008). NMFS is currently investigating the biological effects of the late 1970s climate shift on larval fish assemblages and seabird diets. The most-recent abundance estimates by Gerrodette *et al.* (2008) found significant increases in bottlenose dolphins. Because this species is rarely taken by the tuna purse-seine fishery, the authors suggested that this increase may be due to changes in their habitat.

The NMFS and IATTC are currently working on multi-species population models that incorporate ecosystem data. A study of the tuna-dolphin association has been conducted using tracking, food habits and observer and environmental data (Scott *et al*. in review). Net-tow samples collected in the late 1960s (EASTROPAC cruises) and museum specimens collected prior to the climate shift will be compared with samples collected during the 1986-1990 and 1998-2006 cruises.

Fiedler, P.C., and M.F. Lavin (eds.). 2006. Review of eastern tropical Pacific oceanography Progress in Oceanography, Vol. 69. [Special issue on ETP oceanography]
http://www.sciencedirect.com/science?_ob=PublicationURL&_tockey=%23TOC%235838%232006%23999309997%23624730%23FLA%23&_auth=y&view=c&_acct=C000052003&_version=1&_urlVersion=0&_userid=1206786&_pubType=J&md5=ed05bfebf162161d1d212a77e6cfa137

Redfern, J.V., J. Barlow, L.T. Ballance, T. Gerrodette, and E.A. Becker. 2008. Absence of scale dependence in cetacean-habitat models for the eastern tropical Pacific Ocean. Marine Ecology Progress Series.
http://int-res.com/articles/feature/m363p001.pdf

6. Mortality estimates.

Both the NMFS and IATTC Reports agreed that recent observed mortality estimates were well below the levels that are considered sustainable. Because of the difference between the observed and expected population growth rates, the NMFS Report speculated that there must be additional mortality occurring that is not reported by observers. The NMFS Report discussed possible sources of unreported mortality: the observer's inability to see everything during the set, observer corruption, mortality caused by smaller purse seiners that are not observed, and mortalities that occurred outside the net due to the delayed effects of stress, or the mortality of calves separated from their mothers during the chase. Archer *et al*. (2001; 2004) did report the mortalities of lactating mothers without associated calves, leading to the conclusion that many of these orphaned calves subsequently die, although NMFS population models did not support the notion that additional mortality was occurring, and any additional hidden mortality of orphaned calves was inconsequential and sustainable by the population.

The IATTC staff developed a data screening procedure to identify unusual observer data, particularly as regards dolphin mortality, and a paper on the statistical methodology used in this work has been published (Lennert-Cody and Berk 2007). This procedure is being applied annually to the data of the IATTC, and on a voluntary basis to data of the national observer programs. Work is ongoing on the development of methods for revising reported mortalities in sets that were identified as having potentially unusual data. The staff of the Venezuelan national observer program, with input from IATTC staff, has developed a new data form to collect information on crew activities that may be indicative of: 1) additional rescue efforts, and 2) diver efforts to hide dead dolphins from the observer's view. Data collected on this new form will be analyzed and compared to the results from the data screening algorithm. IATTC and NMFS staffs have been working to implement the NMFS-funded additional sampling program that monitors the unloadings of purse-seine vessels of less than 363 tons of carrying capacity.

Archer, F. T. Gerrodette, A. Dizon, K. Abella, and S. Southern. 2001. Unobserved kill of nursing calves in the tuna purse-seine fishery. Marine Mammal Science 17:540-554.
http://www.blackwell-synergy.com/doi/pdf/10.1111/j.1748-7692.2001.tb01003.x

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

http://fishbull.noaa.gov/1022/archer.pdf

Lennert-Cody, C.E. and Berk, R.A. 2007. Statistical learning procedure for monitoring regulatory compliance: an application to fisheries data. Journal of the Royal Statistical Society Series A Vol. 170 Issue 3:1-19
http://www.blackwell-synergy.com/doi/pdf/10.1111/j.1467-985X.2006.00460.x

7. Development in gear technology and fishing techniques to improve dolphin release.

The NMFS and IATTC Reports did not discuss gear research, although it has been a long-standing area of research of critical importance to the IATTC.

The Mexican tuna-dolphin program in Ensenada has been conducting research on *alerones* (net panels) to improve the backdown procedure.

8. Capture of mature tuna not in association with dolphins.

The NMFS and IATTC Reports did not discuss fishing methods.

The Spanish Institute of Oceanography has previously described its studies to detect tunas acoustically to reduce the catches of juvenile yellowfin and bigeye tunas, and how such techniques could be used to detect large yellowfin tuna not in association with dolphins (Minutes of the 5th meeting of the SAB). An archival-tag tracking study of yellowfin tuna by Schaefer *et al*. (2007) provided information on horizontal and vertical movements that can shed light on this question. Hypotheses to explain the tuna-dolphin association have been tested in a paper by Scott *et al*. that is currently under review.

Schaefer, K.M.. D.W. Fuller, and B.A. Block. 2007. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the northeastern Pacific Ocean, ascertained through archival tag data. Marine Biology 152:503-525
http://www.springerlink.com/content/9576jnw451874xnt/

B. PROPOSED RESEARCH

The Secretariat recommends that the SAB focus on the following research projects, which are currently, or were previously, on the SAB's Work Plan.

1. Simultaneous tracking of dolphins and tuna

During a study conducted in 1992-1993 (Scott *et al*. in review), spotted dolphins and yellowfin tuna were simultaneously tracked to gather information about the tuna-dolphin bond. It was discovered that large yellowfin tuna are not always associated with the dolphins, and that they swim at about the depth of the thermocline. Larger sample sizes are required, however, to determine under what circumstances the tuna-dolphin bond is formed and broken, and help predict where and when large yellowfin may be found not in association with dolphins. Such a study will require a purse-seine vessel to capture both dolphins and tuna in the same set and a research vessel to track the animals. Using the capture and tagging techniques used in 1992-1993, tuna would be tracked using pressure-sensitive acoustic transmitters to monitor their depth and location, while the dolphins would be similarly monitored using radio transmitters and time-depth recorders.

2. Acoustic detection of mature tuna not associated with dolphins

One approach for locating schools of large yellowfin tuna is through the use of active or passive acoustic detection devices (see Spanish studies mentioned above). The technology carried by purse-seine vessels has evolved considerably in recent years, and the Secretariat should update its knowledge base on the acoustic detection equipment that is available and in current use, by carrying out a survey of the this on a vessel-by-vessel basis . Information would include the types of equipment on board, the make and model of the devices, and the range at which they can detect large yellowfin tuna. A questionnaire would be given to all captains to discover how the equipment is used to locate tuna schools. Multiple projects

involving acoustic detection of tunas were discussed at the 9th Stock Assessment Review Meeting, and the information collected could assist in collaborative research.

3. Updating estimates of N_{min} and Stock Mortality Limits

Because results from the most recent NMFS abundance survey are now available, a workshop could be convened to update the estimates of N_{min} that were last done by the Technical Workshop for Calculating Nmin in 2006 (IATTC Special Report 14), and to consider updating the current Stock Mortality Limits (SMLs) which are based on abundance estimates that are 20 years old. For background material related to this topic and the calculation of new N_{min} values, see Document SAB-06-03 ADD REV.

Appendix A. SAB Work Plan for 6th Meeting, June 2008.

	Research Topics	Proposed Studies	SAB Recommendations
1.	Prevalence and significance of cow-calf separation.	A) Aerial photogrammetry B) At-sea observations C) Spatial distribution of chase time	A-C) Conduct research to discover evidence of cow-calf separation during chase.
2.	Life history and fishery-related stress effects studies.	A) Life history studies 1) Reproductive parameters/ vital rates 2) Food habits 3) Trophic interactions B) Stress effects 1) Necropsy studies	A-B) Resume sampling program to conduct studies on these topics.
3.	Review of currently available estimates of abundance for dolphin stocks.	A) Review current abundance estimates	A) Review 2006 survey estimates.
4.	Stock assessment of coastal spotted dolphins	A) Genetics and taxonomy research B) Historical mortality, abundance, and status of any new stocks.	A-B) Maintain on Work Plan.
5.	Ecosystem effects.	A) Trends in other EPO cetaceans B) Ecosystem models C) Effect of large-scale changes in 1970s D) Carrying capacity and R_{max} for dolphins	A-D) Maintain on Work Plan.
6.	Mortality estimates.	A) Historical mortality estimates. B) Potential unobserved sources of mortality 1) Comparison of observer programs 2) Class-5 vessels 3) Other fisheries.	A) Review historical estimates B) Monitor ongoing comparisons for IRP[2] and maintain on Work Plan.
7.	Population modeling	A) Model effects of unobserved mortality B) Other population models	A) Expand NMFS simulation studies to prioritize research. B) Maintain on Work Plan
8.	Development in gear technology and fishing techniques to improve dolphin release.	A) Net panels B) Net profilers	A-B) Maintain on Work Plan
9.	Capture of mature tuna not in association with dolphins.	A) Simultaneous tracking of dolphins and tuna	A) Maintain on Work Plan

[2] Pending consultation with the Parties regarding confidentiality issues.