Workshop to Design an Experiment to Determine the Effects of Longline Gear Modification on Sea Turtle Bycatch Rates

(Workshop para a elaboração de uma experiência que possa diminuir as capturas acidentais de tartarugas marinhas nos Açores)

2-4 September 1998
Horta, Azores, Portugal

Edited by:
Alan B. Bolten
Helen R. Martins
Karen A. Bjorndal

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-19
December 2000

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Alan B. Bolten
Archie Carr Center for Sea Turtle Research
and Department of Zoology
P.O. Box 118525
University of Florida
Gainesville, FL 32611 USA

Helen R. Martins
Departamento de Oceanografia e Pescas
Universidade dos Açores
PT-9900 Horta Portugal

Karen A. Bjorndal
Archie Carr Center for Sea Turtle Research
and Department of Zoology
P.O. Box 118525
University of Florida
Gainesville, FL 32611 USA

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Norman Y. Mineta, Secretary

National Oceanic and Atmospheric Administration
D. James Baker, Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service
Penelope D. Dalton, Assistant Administrator for Fisheries

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Acknowledgments

This workshop was funded by the U.S. National Marine Fisheries Service. Additional support was provided by the University of the Azores, Department of Oceanography and Fisheries; the Azores Ministry of Agriculture and Fisheries; and the Archie Carr Center for Sea Turtle Research, University of Florida. We are grateful for the support of Barbara Schroeder and Earl Possardt of the U.S. National Marine Fisheries Service.

Workshop to Design an Experiment to Determine the Effects of Longline Gear Modification on Sea Turtle Bycatch Rates

Agenda

1 September 1998: All out of town participants arrive in Horta

2 September 1998: Workshop Day 1 (Location: Camara do Comercio)

9:30 – 10:00	Opening. **Helen Martins** (Workshop Moderator) Introduction of Participants Welcome. **Helder da Silva** Workshop Schedule. **Alan Bolten**
10:00 – 10:50	Background Presentations (Background presentations will be limited to 15 minutes with an additional 10 minutes for discussion) Objectives of the Workshop. **Mário Pinho** and **Eduardo Isidro** Review of swordfish longline fishery in the Azores (techniques, equipment, bait, etc.). **Alexandre Silva**
10:50 – 11:15	Coffee Break
11:15 – 12:30	Background Presentations, continued Review of available information on turtle bycatch in longline fisheries in the Azores. **Manuel Serpa** Review of longline observer program in the Azores. **Rui Prieto** presented by **Alexandre Silva** Review of POPA (Observer program for fisheries in the Azores) with respect to sea turtle observations. **Rogério Feio**
12:30 – 14:00	Lunch (We will eat as a group at O Barao)
14:00 – 14:30	Review of life history of sea turtles in the waters around the Azores. **Alan Bolten**
14:30 – 15:30	Presentation of an experimental design to stimulate discussion **Eduardo Isidro** and **Mário Rui Pinho**
15:30 – 16:00	Coffee Break
16:00 – 17:30	Experimental Design and Analysis Discussion of experimental variable, design and analysis
17:30	Adjourn Day 1

3 September 1998: Workshop Day 2

9:30 – 11:00	Review of Day 1. **Alan Bolten** Schedule of Day 2 Development of experimental design and analysis.
11:00 – 11:30	Coffee Break
11:30 – 12:30	Development of experimental design and analysis, continued
12:30 – 14:00	Lunch (We will eat as a group at O Barao)
14:00 – 15:30	Development of experimental design and analysis, continued
15:30 – 16:00	Coffee Break
16:00 – 17:30	Finalize experimental design and analysis Begin discussion on the logistics for conducting the experiment (time of year, location, boats, etc) and development of budget
17:30	Adjourn Day 2

4 September 1998: Workshop Day 3

9:30 – 11:00	Review of Day 2. **Alan Bolten** Schedule of Day 3 Discuss and finalize logistics for conducting the experiment.
11:00 – 11:30	Coffee Break
11:30 – 12:30	Develop budget for conducting the experiment.
12:30 – 14:00	Lunch (We will eat as a group at O Barao)
14:00 – 15:30	Finalize budget for conducting the experiment.
15:30 – 16:00	Coffee Break
16:00 – 17:30	Workshop Review and Conclusions.
	Distribute assignments for Workshop Report
	Adjourn Workshop

Workshop para a elaboração de uma experiência que possa diminuir as capturas acidentais de tartarugas marinhas nos Açores

Agenda

1 de Setembro 1998:	Chegada dos convidados à cidade de Horta (Alojamento: Horta Hotel)
2 de Setembro 1998:	**Workshop Dia 1 (Localização: Câmara do Comércio, Travessa da Misericórdia)**
9:30 - 10:00	Abertura. **Helen Martins** (Moderadora do Workshop) Apresentação dos Participantes Boas vindas. **Helder da Silva** Agenda do Workshop. **Alan Bolten**
10:00 - 10:50	Apresentações genéricas (As apresentações terão um limite máximo de 15 minutos, com 10 minutos adicionais para a discussão) Objectivos do Workshop. **Mário Pinho** e **Eduardo Isidro** Síntese da pesca do Espadarte com palangre, nos Açores (técnicas, equipamento, isco, etc.). **Alexandre Silva**
10:50 - 11:15	Intervalo para Café
11:15 - 12:30	Apresentações genéricas, continuação Revisão da informação disponível sobre o capturas acidentais de tartarugas em pesca de palangre, nos Açores. **Manuel Fernando Serpa** Análise do programa de observação da pesca de palangre nos Açores. **Rui Prieto**, apresentado por **Alexandre Silva** Análise do POPA (Programa de Observadores para as Pescas dos Açores) no que diz respeito a observações de tartarugas marinhas. **Rogério Feio**
12:30 - 14:00	Almoço (A refeição será em grupo, no restaurante O Barão)
14:00 - 14:30	Estudo da vida das tartarugas marinhas nas águas dos Açores. **Alan Bolten**
14:30 – 15:30	Apresentação de um desenho experimental, a fim de estimular a discussão. **Eduardo Isidro** e **Mário Pinho**
15:30 - 16:00	Intervalo para Café
16:00 - 17:30	Desenho Experimental e Análise Discussão das variáveis experimentais, desenho experimental e analise.

17:30	Encerramento do Dia 1

3 de Setembro 1998: Workshop Dia 2

9:30 - 11:00	Síntese do Dia 1. **Alan Bolten** Agenda para o Dia 2 Desenvolvimento do desenho experimental e análise
11:00 - 11:30	Intervalo para Café
11:30 - 12:30	Desenvolvimento do desenho experimental e análise (continuação)
12:30 - 14:00	Almoço (A refeição será em grupo no restaurante O Barão)
14:00 - 15:30	Desenvolvimento do desenho experimental e análise, (continuação)
15:30 - 16:00	Intervalo para Café
16:00 - 17:30	Finalização do tema: Desenho Experimental e Análise Começo da discussão sobre logística no decorrer da experiência (altura do ano, localização, embarcações, etc.) e estipulação de um orçamento
17:30	Encerramento do Dia 2

4 de Setembro 1988: Workshop Dia 3

9:30 - 11:00	Síntese do Dia 2. **Alan Bolten** Agenda para o Dia 3 Discussão e conclusão sobre a logística para o decorrer da experiência
11:00 - 11:30	Intervalo para Café
11:30 - 12:30	Elaboração do orçamento para a concretização do projecto.
12:30 - 14:00	Almoço (A refeição será em grupo no restaurante O Barão)
14:00 - 15:30	Finalização da estipulação do orçamento para a concretização do projecto
15:30 - 16:00	Intervalo para Café
16:00 - 17:30	Síntese do Workshop e Conclusões Distribuição de tarefas para o Relatório do Workshop Encerramento do Workshop

Workshop Participants

A. Director of Fisheries of the Regional Government of the Azores

Helder da Silva

B. University of the Azores, Department of Oceanography and Fisheries, Horta

Alexandre Silva

Eduardo Isidro

Helen Martins

João Tátá Regala

Jorge Fontes

Manuel Fernando Serpa

Mário Pinho

Rogério Ferreira

Rogério Feio

Verónica Neves

C. Directorate of the Nature Conservation Service of the Azores

Manuel Veríssimo

D. Commercial fishermen

Genuíno Madruga, Horta

Jorge Gonçalves, Horta

José Sebastião Nunes, Corvo

José Maria Ferreira Faria, Flores

E. Participants from the United States

Alan Bolten (Archie Carr Center for Sea Turtle Research, University of Florida)

Jerry Wetherall (US National Marine Fisheries Service, Hawaii)

Opening Remarks

Helen R. Martins

Departamento de Oceanografia e Pescas
Universidade dos Açores
PT-9900 Horta, Portugal
E-mail: hmartins@dop.uac.pt

Ladies and gentlemen,

I am very happy to have the honour to open this workshop and to be your moderator during these 3 days. I do think that we have managed to bring together the best people possible to reach our objective.

First of all it is important that we get to know each other well in order to have a fruitful discussion. I would ask each of you to present yourselves by your name, place of work, and other information of interest. My name is Helen Martins or Helena Martins in Portuguese version. I am a researcher at the Department of Fisheries and Oceanography (DOP) of the University of the Azores, where I have worked for the last 22 years. (Other participants who introduced themselves in turn were: Helder Marques da Silva, Alexandre Silva, Eduardo Isidro, João Tátá Regala, Manuel Fernandes Serpa, Mario Pinho, Rogério Ferreira, Rogério Feio, Veronica Neves, Manuel Verissimo, Genuino Madruga , Jorge Gonçalves, José Sebastião Nunes, Jose Maria Ferreira Faria, Alan Bolten, and Jerry Wetherall).

The topic of this workshop is the problem of marine turtles. These turtles constitute a group of ancient reptiles that already lived in the oceans more than 100 million years ago and existed in the time of the dinosaurs. They represent a distinct part of the bio-diversity of our planet. In the 18th and 19th centuries turtles were very abundant, and populations existed with more than a million individuals. However, during the last hundreds of years humans have destroyed the ability of turtles to maintain their numbers which have decreased drastically through intentional and accidental capture by fishermen, destruction of feeding areas and resting places, destruction of nesting beaches, and, more recently, pollution of the oceans.

Today almost all populations show decline, some at a drastic pace and some are already extinct. Worldwide, there is a growing concern with accidental capture of sea turtles in commercial fisheries. Today all the turtle species in the Azores (5 species) are included in the Red List of IUCN as endangered and all marine turtles are included in CITES and in CMS. It is evident that a program to protect these animals from extinction has to be carried out on a global scale and through governments, scientists, fishermen and the general public. I do think that here in the Azores we have the opportunity to achieve such a collaboration. The result of this workshop may have importance also for other regions of the world's oceans.

Thank you!

Abertura

Minhas Senhoras e Meus Senhores

Estou muito contente por ter a honra de abrir este Workshop e para ser a sua moderadora durante estes 3 dias. Penso que conseguimos reunir as melhores cabeças possíveis para chegar ao nosso objectivo.

Antes de mais é importante que nos conheçamos bem para ter uma discussão frutífera. Peço a cada um que diga o seu o nome e o seu local de trabalho e outras observações de interesse. Eu chamo-me Helen Martins ou Helena Martins na versão Portuguesa. Sou investigadora de Departamento de Oceanografia e Pescas, onde trabalhei deste o princípio, ou seja desde hà 22 anos. (Outros participantes: Helder Marques da Silva, Alexandre Silva, Eduardo Isidro, João Tátá Regala, Manuel Fernandes Serpa, Mario Pinho, Rogério Ferreira, Rogério Feio, Veronica Neves, Manuel Verissimo, Genuino Madruga , Jorge Gonçalves, José Sebastião Nunes, Jose Maria Ferreira Faria, Alan Bolten, Jerry Wetherall.)

O nosso assunto neste Workshop é o problema das tartarugas marinhas. Estas tartarugas são um grupo de repteis muito antigos. Já existiam nos mares há 100 milhões de anos, viviam no tempo dos dinossáurios, e representam uma parte distinta da biodiversidade do mundo. Nos séculos XVIII e XIX as tartarugas eram muito abundante e tiveram populações que contavam um milhão ou ainda mais. Mas nas últimas centenas de anos o Homem destruiu a habilidade das tartarugas de manter os seus números, que baixaram drasticamente através de capturas intencionais e capturas acidentais da pesca, destruição de áreas de alimentação, destruição dos locais de desova e descanso e, mais recentemente, a poluição dos oceanos.

Hoje em dia quase todas as populações estão em declínio, algumas a um ritmo drástico e outras já estão extintas. Cada vez mais há uma crescente preocupação para as capturas acidentais.

Hoje em dia todas as tartarugas dos Açores (5 espécies) estão incluídas na lista vermelha da União Internacional de Conservação da Natureza como em perigo ou vulneráveis e todas as tartarugas marinhas estão incluídas na Convenção de Comercio Internacional de Espécies em Perigo de Fauna e Flora Selvagem (CITES) e na Convenção de Conservação de Espécies Migratórios de Animais Selvagens (CMS). É evidente que uma força para proteger estes animais da extinção tem que ser exercida a uma escala global e através da colaboração entre governos, cientistas, pescadores e o publico em geral. Eu penso que aqui nos Açores temos a oportunidade de conseguir uma colaboração deste género. Os resultados deste workshop podem ter importância também para outras regiões dos oceanos.

Obrigada!

The Swordfish Fishery in the Azores: an Overview

Alexandre Aires da Silva

Departamento de Oceanografia e Pescas
Universidade dos Açores
PT-9900 Horta, Portugal
E-mail: alexsilva@dop.uac.pt

This paper aims to provide a background about the swordfish fishery in the Azores within the scope of the *I Workshop on Sea Turtle Bycatch*, Horta, 2-4 September 1998.

Historical Background of the Fishery

The swordfish (*Xiphias gladius*) fishery in the Azores has already been described (Pereira, 1988; Simões and Silva, 1994; Simões, 1995). The fishery started in 1987 following the strong incentives for swordfish exploitation given by the *VII Azorean Fisheries Week* as well as the good experimental fishing results obtained during 1985-1986 (Fernandes 1987, Pousa, 1987). Prior to 1987, the capture of swordfish in the Azores was considered a bycatch of the demersal fishery with landings not exceeding 30 tons per year.

Fleet Identification

The longline fleet targeting swordfish in the Azores can be first divided into two main components according to place of registration: Azores and Mainland Portugal fleets. The Azorean fleet can be further classified into three main components according to physical characteristics of the vessels and fishing regime: the open-deck wooden boats (ODWB), small-size cabin-deck boats (CDB_1) and large size cabin-deck boats (CDB_2). The average physical characteristics for each of the fleet components are given in Table 1.

Table 1. Average physical characteristics for each component of the swordfish fleet operating in the Azores. ODWB: open-deck wooden boats; CDB_1: small-size cabin-deck boats; CDB_2: large-size cabin-deck boats; MPB - Mainland Portugal boats.

Fleet	Fleet component	Overall length (m)	Engine power (HP)	Gross tonnage (GRT)
Azores	ODWB	10	37	5
	CDB_1	14	173	27
	CDB_2	28	581	157
Mainland Portugal	MPB	26	516	122

The open-deck wooden boats (ODWB; Figure 1.A) consist of small-size fishing boats mainly operating within 3 miles off the coasts of S. Miguel Island (Simões, 1995). This artisanal fleet fishes for swordfish during the summer season and shifts to the demersal fish community in winter months. Longline sets with an average number of 800 hooks-per-set are carried out on a daily trip basis. The open-deck wooden boats entered into the fishery in 1991, and have increased in numbers from that year (Figure 2.A). Seventeen fishing permits were given to this fleet component in 1998.

Like the ODWB fleet component, the small-size cabin-deck boats (CDB_1; Figure 1.B) target swordfish during the summer season and shift to the demersal fish community in winter months. This type of boat lacks freezing capacity, staying for about one week at sea. One longline set is carried out per day using an average number of 1500 hooks. The fishing effort is mostly localized around the coastal areas and the fishing banks of the Central Island Group. This fleet component exhibited a strong increase in numbers during the early 1990s, peaking at 40 permits in 1993 (Figure 2.A). After that period, the number of permits given to component CDB_1 has declined continuously to 26 in 1998.

Large-size cabin-deck boats fishing for swordfish throughout the year represent the third Azorean fleet component (CDB_2; Figure 1.C). This component conducts fishing campaigns that can take about a month at sea due to the large freezing capacity of the vessels. One longline set with an average number of 2500 hooks is carried out on a daily basis. During the winter months the large-size cabin-deck boats extend their fishing areas outside the Azorean EEZ. Number of fishing permits for the component CDB_2 reached a maximum of 20 permits in 1994, then declined to 9 permits in 1998 (Figure 2.A).

The Mainland Portugal fleet fishing for swordfish in the Azores is similar to the Azorean CDB_2 component in physical characteristics of vessels and fishing regime (*cf*. Table 1; Figure 1.C). This fleet mostly lands in the Portuguese and Spanish Mainland, in the harbors of Aveiro and Vigo, respectively. Unlike the Azorean fleet, the number of fishing permits given to the Mainland fleet exhibited a strong increasing trend during the 1990s (Figure 2.B). A total of 15 permits was given to this fleet in 1998.

Fishing Gear and Methods

The longline gear consists of a mainline to which branchlines with hooks are sequentially attached at a fixed distance (Figure 3). The mainline is suspended in the water column with a system of buoys attached by floatlines. The gear configuration can slightly change according to the maximum desired fishing depth (i.e., changing the length of the floatlines).

Two different types of longline gear are used in the swordfish fishery in the Azores: the Spanish and the US longline. Although both gears mostly use hook number 17/0, they differ in the type of the mainline, arrangement of gear components, and crew number (Fernandes, 1987).

The type of mainline used in the Spanish longline is twisted polyethylene. In the US gear, the mainline is 3.50 monofilament nylon. All of the gear components of the Spanish longline (i.e., the mainline, branchlines and buoys) are assembled on land. The US longline components are stored separately onboard, with the gear being continuously prepared during the set. Lastly, the operation of the two types of gear involves a different crew number. The fishing crew for Spanish longline requires 15 men; this number is reduced to 7 men for US longline operation.

Although the Azorean fleet has adopted both the Spanish and US gears, the acceptance of the former has been gradually increasing in the region. The Mainland Portugal fleet mainly operates with the US longline gear.

The swordfish fishing is carried out during night hours due to the negative phototropism exhibited by the species. For this purpose, the longline set finishes at dusk and the hauling operation starts at dawn. While the main type of bait used by the Azorean longline fleet is Spanish mackerel (*Scomber japonicus*), the Mainland Portugal fleet uses squid as well. The use of light-sticks in the swordfish fishery in the Azores is not a common practice.

Fishing Areas

Most of the fishing effort carried out by the Azorean and Mainland Portugal swordfish fleets is carried out in the waters around the Azores. A total of 5774 longline sets was reported in fishing logbooks during the period 1993-1998 (see Figure 4 for distribution map). A proportion of 87.2% (n=5037) of these fishing operations are confined to the area 36-48º N, 18º-42º W (ICES X), which contains most of the Azorean EEZ. Although the incidence is low, the distribution of the Portuguese longline fleet in the North Atlantic extends to the waters off the Iberian Peninsula and the African coast.

Identification of Bycatch

Bycatch of the swordfish fishery in the Azores consists mainly of pelagic sharks, particularly the blue shark (*Prionace glauca*) and the shortfin mako (*Isurus oxyrinchus*) (Silva et al., 1996). Other species–such as the common thresher (*Alopias vulpinus*), bigeye thresher (*Alopias superciliosus*), smooth hammerhead (*Sphyrna zygaena*), tope (*Galeorhinus galeus*) and the galapagos shark (*Carcharhinus galapaguensis*)–are also represented in the shark bycatch. The bigeye (*Thunnus obesus*) and blue marlin (*Maikaira nigricans*), respectively, represent most of the tuna and billfish bycatch.

Bycatch of marine turtles in longlines targeting swordfish in the Azores is poorly known. Information on this issue was presented during this workshop (see Serpa and Prieto et al. in this volume). The loggerhead turtle (*Caretta caretta*) is the species most commonly caught. The leatherback (*Dermochelys coriacea*) has already been recorded during longline experimental fishing activities carried out by the Department of Oceanography and Fisheries, University of the Azores (Silva et al., 1996).

The bycatch of marine birds associated with the longline fishery in the Azores is virtually unknown.

Fishing Seasons

Two fishing seasons can be identified for the longline fishery targeting swordfish in the Azores: swordfish season and blue shark season. Catch rates for blue shark and swordfish exhibit a pronounced seasonal and asynchronic nature (Figure 5). While the highest catch levels of the former species are obtained in the Spring, the fishing season for the latter targeted species is from May to December. Blue shark bycatch represents a major proportion of the total catch taken by the fishery, reaching a minimum of 22% and a maximum of 86%, respectively, during October and May (Figure 6). Shortfin mako catch levels are less than 5% of the total catch during the entire year.

Landings of Swordfish and Pelagic Sharks

Reported landings of swordfish, blue shark and shortfin mako in the Azores during the period 1993-1997 are shown in Figure 7. Landings of swordfish exhibit a peak of 463 metric tons (mt) in 1995, followed by a decline to 178 mt in 1997. Reported catches of blue shark increased from 1993 to 1996, peaking in 1996 at 328 mt. After that period, landings declined to 92 mt in 1997. Although the discard levels associated with the swordfish fishery are not quantified, blue shark discards by the Azorean longline fleet are believed to be high. This conclusion is supported by the non-existence of a stable market and little demand for blue shark products within the Azorean region. Discard levels for this species by the Mainland's longline fleet are known to be extremely low. This results from the existence of two asynchronic fishing seasons for the targeted swordfish and for blue shark in the Azores (Figure 5), and the increasing demand for shark products in European markets (Fleming and Papageorgiou, 1997).

Landings of shortfin mako in the region averaged about 8.2 mt per year during 1993-1997, with a maximum of 12 mt landed in 1995. Discard levels for this shark are extremely low due to the high quality of its meat.

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Figure 1. Components of the longline fleet fishing for swordfish in the Azores:
A - Azorean open-deck wooden boats (ODWB);

Information on Accidental Capture of Marine Turtles in the Azores

Manuel F. Serpa

Departamento de Oceanografia e Pescas
Universidade dos Açores
PT-9900 Horta, Portugal
E-mail: fserpa@dop.uac.pt

Unfortunately nothing has previously been recorded on accidental capture of sea turtles by the longline fleet in the Azores. This report is based on the personal experience of the author who has had the opportunity to take part in several longline fishing surveys from 1989 to 1996. This is a summary of my experiences.

November 1989 to February 1990, F/V "António Duarte". Experiment with winter longlining for tuna.
Results of 32 sets: 910 blue sharks, 114 swordfish, 3 bigeye, 2 albacore, 8 mako sharks, **2 loggerheads** and **3 leatherback turtles**.
Remarks: The small number of turtles was due to the fact that it was winter and that the target species was tuna which means that the lines were set too deep to catch turtles.

June to September 1990, F/V "IMAQ FISH". Experiment with longlining for tuna from Azores to Canada. However, as few tuna were caught, the gear was changed to target swordfish.
Results from 30 settings: 4 bigeye, 7 yellowfin, 9 bluefin, 38 blue sharks, 39 swordfish, **20 loggerheads** and **3 leatherback turtles**.
Remarks: Several turtles were caught in June and July, always on the hooks close to the buoys. At the end of July, we caught several large turtles (20 – 30 kg) WNW of Flores, Azores. Farther north, when 300 nautical miles from the Grand Bank, no more turtles were seen.

November 1990, F/V "IMAQ FISH". Experiment in longlining for swordfish.
Results: 2 bluefin, 1 bigeye, 2 yellowfin, 1 albacore, 4 mako sharks, 104 swordfish, **8 loggerheads** and **3 leatherback turtles**.

March to April 1991. Japanese longliner for tuna.
Results: **3 loggerheads,** and **2 leatherback turtles**.
Remarks: Very few turtles due to low temperature (15º to 16º C) and that the line was set as deep as 80 m, the target species being tuna.

September to October 1996, F/V "S. Miguel". Longlining for swordfish.
Results in 22 sets: 10 tons of swordfish, 12 tons of shark, 0.5 tons of tuna, and about **100 loggerhead turtles**.
Remarks: 90% of the turtles were caught at Mar da Prata, south of S. Miguel and the Bank of S. Mateus, south of Pico. The water temperature was 20-22° C. The bait was 75% mackerel and 25% squid.

November to December 1996, F/V "Mar de Cristal". Longlining for swordfish.
Results in 16 sets: 8 tons of swordfish, 6 tons of shark, 300 kg of bigeye, and **40 loggerhead turtles**, with an average weight of about 30 kg.
Remarks: Each set had an average of 900 hooks. The bait was 75% mackerel, 15% squid, and 10% shark filets. The number of fishing boats in the area varied from 2 to 4. Most of the turtles were captured in November at the bank of S. Mateus, south of Pico, where up to 6 were taken in one day.

Concluding Remarks

The turtles seem to be more likely to be caught from June to the middle of August, and most of them were caught when the fisheries were directed at swordfish. One also observes that the majority are caught on hooks close to the buoys.

My experience is that, at the end of the summer when few turtles are seen on the surface, the turtles that are caught are larger. Thus, in July and August one finds individuals of variable sizes, while from September onwards one finds more larger individuals. From my experience, the number of turtles caught in the fisheries diminishes from the end of August to the middle of September and increases again in October and November especially under favorable weather conditions.

Most of the turtles are not hauled onboard. Especially on the larger vessels, they are rejected by the fishermen by cutting the line. Only rarely, when the sea is smooth, is the turtle freed from the hook onboard and put out to sea.

The number of turtles that manage to free themselves from the hook at sea is insignificant. This only happens with large boats at great speed under bad weather conditions.

Only once in my experience was a turtle hauled aboard dead. In general, the turtles did not show signs of being weak or tired.

I hope that through discussion and dialogue it will be possible to develop these ideas as well as other questions regarding the accidental capture of turtles.

Tabela 1 - Etapas da captura com anzol e variáveis principais. As variáveis consideradas mais importantes estão sublinhadas.

ETAPAS	VARIÁVEIS
ATRACÇÃO: (Attraction)	Isco, profundidade, variáveis ambientais vs factores biológicos da espécie (e.g. correntes, luz ou transparência da água, distribuição vertical e horizontal da espécie, comportamento alimentar, atracção pelas boias, etc.).
CAPTURA: (Capture)	Tamanho e forma do anzol vs factores biológicos da espécie (outros factores e.g. espaçamento dos anzóis, saturação do aparelho, competição inter e intraespecífica, comportamento alimentar, tamanho da boca, etc.).
ESCAPE: (Escape)	Tamanho e forma do anzol, tipo de estralho vs factores biológicos da espécie (outros factores e.g. aprendizagem através de contactos prévios com a arte, comportamento alimentar e forma como engole o anzol, etc.).

Experiment to Evaluate Gear Modification on Rates of Sea Turtle Bycatch in the Swordfish Longline Fishery

Objective

Conduct an experiment to evaluate effects of gear modification on rates of sea turtle bycatch in the swordfish longline fishery in the Azores. The primary variables to be evaluated are hook shape ("J" Anchora vs. Mustad circle/curve), bait (squid vs. mackerel), and buoy line depth (3 fathoms vs. 6 fathoms). Although the primary objective is to evaluate rates of sea turtle bycatch, the effect of gear modification on the location of hooking (e.g., mouth vs. esophagus) will also be evaluated. The location of hooking has very important implications for the survival of the hooked turtles.

Justification

1. Results from this experiment will have broad application and can be applied to swordfish longline fisheries around the world.

2. The sea turtle population impacted by the swordfish longline fishery in the Azores is the early juvenile pelagic stage for turtles that nest in the southeast USA.

Background

The problem of sea turtle bycatch in longline fisheries has been recognized worldwide (for review, see Balazs and Pooley 1994, Williams et al. 1996). Bolten et al. (1994) presented preliminary data on bycatch of loggerhead sea turtles (*Caretta caretta*) in the swordfish longline fishery in the Azores. The waters around the Azores are an important developmental habitat for the pelagic stage of the Atlantic loggerhead population. Using mtDNA sequence analyses, Bolten et al. (1998) determined that the source rookeries for this pelagic population are primarily in the southeastern USA. Therefore, the nesting population of loggerheads in the southeast USA is the primary population impacted by the swordfish longline fishery in the Azores.

Design of the Experiment

An experiment was designed using "American Gear" configuration (nylon line with steel leader) with the following three variables:

1. hook type: "J" Ancora 17/0 (Spanish) vs. Mustad circle/curve
2. bait: squid vs. mackeral
3. depth of buoy line: 3 fathoms vs. 6 fathoms.

Workshop participants identified other variables (e.g., light sticks), but there was consensus that the three variables chosen were the most important. The experiment will be conducted during the 4 primary months of the swordfish fishery in the Azores (June, July, October, and November). A commerical longline fishing vessel (with a commercial crew) from the Azores will be chartered to conduct the experiment. The experiment will consist of a minimum of 60 sets (approximately 15 sets per month) with 960 hooks per set. For each set at each of the two buoy line depths (3 fathoms [n = 30 sets] or 6 fathoms [n = 30 sets]), the experimental design will allow for the following comparisons to be statistically evaluated:

Hook 1[A] vs. Hook 2[B]	480 hooks for each treatment
Bait L[C] vs Bait C[D]	480 hooks for each treatment
Hook1 Bait L vs Hook1 Bait C vs Hook2 Bait L vs Hook2 Bait C	240 hooks for each treatment

[A] Hook 1 = “J” Ancora
[B] Hook 2 = Circle/Curve Mustad
[C] Bait C = Cavala = mackerel
[D] Bait L = Lula = squid

The following diagram illustrates the experimental array. The starting order of bait and hook type will be randomized each day to avoid position effect within a gear array. Because every experimental variable change is associated with a major gear change, this experimental array will faciliate changes in variables and data collection. For example, bait type will change at every large buoy and hook type will change at every radar reflector buoy.

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 |>                      |>                     |>                     |>
OoooOoooOoooOoooOoooOoooOoooOoooOoooOoooOoooOoooOoo… continued
|____||____||___||____||___||____||___||___||____||___||____||___||___…
Bait C    L     C     L     C     L     C    L     C     L     C     L     C
(n=24 hooks for each bait unit = basket)

|___________________||_________________||__________________||________…
        Hook  1                 Hook 2                   Hook 1          Hook 2
        n=96 hooks              n=96                     n=96            n=96
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|> = radar reflector buoy
O = large buoy
o = small buoy

1. The buoy line will be either 3 fathoms or 6 fathoms
2. There will be 6 hooks (with 9-meter leaders) on each mother line; hooks will be spaced at 25-30 m.

Schedule

An excellent window of opportunity now exists to pursue this experiment in the Azores because of both political will and interest from the commercial longline fleet in the Azores. We propose that the experiment begin in June 1999.

Literature Cited

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Editors' Note

The Workshop presented in these proceedings brought together scientists, managers, commercial fishermen, and conservationists to identify the important variables for an experiment and to develop the experimental design reported above. However, following the Workshop, further power analyses of the experimental design (see J. Wetherall's chapter in this report) indicated that the number of variables should be reduced to ensure that statistically rigorous analyses would be possible. The US National Marine Fisheries Service awarded the Archie Carr Center for Sea Turtle Research at the University of Florida a contract to conduct the modified experiment in collaboration with the University of the Azores (DOP/Horta). The modified experiment will evaluate the effect of 3 different types of hook (Mustad # 76800 D 9/0 [straight J hook], Mustad # 76801 D 9/0 [reversed/offset J hook], Mustad # 39960 ST 16/0 [circle hook]) on sea turtle bycatch and the target species in the swordfish longline fisheries in the Azores. There are to be 100 sets of 1500 hooks per set with the hook types individually alternating throughout the set with bait kept constant (squid). There will be 8 hooks between each buoy to ensure that hook type and hook position vary relative to the buoys. The experiment is to be conducted from July - December 2000.

Statistical Power of the Azores Longline Experiment

Jerry A. Wetherall

National Marine Fisheries Service
2570 Dole Street
Honolulu, HI 96822 USA
email: jwethera@honlab.nmfs.hawaii.edu

Objective

The objective of this analysis was to estimate the statistical power of F tests of the main treatment effects in a 2-way factorial experiment with 3 treatment levels for the first factor (factor A) and 2 levels for the second factor (factor B), assuming both effects are fixed. This ANOVA design is applicable to a swordfish longline experiment planned for the Azores to assess the effects of longline gear manipulation on incidental take rates of loggerhead turtles. Each longline set is considered a randomized block or replicate and the experimental sampling unit is assumed to be a 24-hook basket of longline gear. Within each longline set, each of the 6 treatment combinations is repeated 7 times.

For the purposes of this exercise assume that the factors have independent and additive effects; i.e., there are no treatment interactions. Let μ_{ij} denote the average treatment response within an experimental unit (i.e., the mean number of turtles taken per 24-hook basket) when factor A is at level i and factor B is at level j (i=1, 2, 3; j=1, 2). In terms of the experimental factors, the mean response for treatment combination {i,j} is:

$$\mu_{ij} = \mu_{11} + (i - 1)\ \delta_A + (j - 1)\ \delta_B \qquad \text{for } i = 1, 2, 3 \text{ and } j = 1, 2$$

where μ_{11} is the average response under "base conditions", defined as the treatment combination giving the lowest average take rate. The symbols δ_A and δ_B are increments in the mean response relative to the base conditions associated with factors A and B, respectively. In a balanced experiment with this design the overall mean take rate for the experiment is:

$$\mu_{\cdot\cdot} = \mu_{11} + \delta_A + \tfrac{1}{2}\ \delta_B\,.$$

where a dot subscript indicates averaging over all levels of a factor.

Under the 2-way ANOVA, F statistics are generated that provide tests of the null hypotheses:

$$_AH_0\colon \mu_{i.} = \mu \qquad \text{for all } i$$

and

$$_BH_0\colon \mu_{.j} = \mu \qquad \text{for all } j$$

against the alternative that at least one of the marginal means for each factor differs from μ. The power of the F tests was estimated with respect to specific alternative hypotheses. In particular, power was computed with respect to the alternative hypotheses:

$_AH_A$: $\mu_{1.} = \mu - \delta_A$
$\mu_{2.} = \mu$
$\mu_{3.} = \mu + \delta_A$

and $_BH_A$: $\mu_{.1} = \mu - ½\ \delta_B$
$\mu_{.2} = \mu + ½\ \delta_B$

These are equivalent to:

$_AH_A$: $\mu_{2.} = \mu_{1.} + \delta_A$
$\mu_{3.} = \mu_{1.} + 2\ \delta_A$

and $_BH_A$: $\mu_{.2} = \mu_{.1} + \delta_B$

Azores Design

For the Azores experiment, the A factor was assumed to be hook type, to be studied at 3 levels: circle hook, straight J hook and offset J hook. The B factor is bait type, to be tested at 2 levels: squid and mackerel. The table of treatment means looks like this:

Hook Type	**Bait Type**		Row Means
	Squid	Mackerel	
Circle	μ_{11}	μ_{12}	$\mu_{1.}$
Straight J	μ_{21}	μ_{22}	$\mu_{2.}$
Offset J	μ_{31}	μ_{32}	$\mu_{3.}$
Column Means	$\mu_{.1}$	$\mu_{.2}$	μ

It was assumed that under current conditions swordfish longliners in the Azores use primarily straight J hooks baited with either squid or mackerel. Thus current conditions are essentially indicated by the second row mean, $\mu_{2.}$ (the shaded cell in the table above). Note that the average take rate in the experiment, μ, will be equal to $\mu_{2.}$, the assumed mean take rate for the "current" conditions.

Parameter Settings

Statistical power of the F test depends on (1) sample size (number of experimental sampling units); (2) the magnitude of the treatment effects to be detected; (3) variation in treatment effects (responses) among sampling units; and (4) Type I error probability (α level). These conditions were specified as follows:

(1) The overall sample size was fixed at 80 longline sets x 6 treatment combinations x 7 repeat observations or 3,360 baskets. Each longline set (replicate) involves 42 baskets and 1,008 hooks.

(2) The magnitude of the treatment effects depends on the average take rate under base conditions (μ_{11}), and the increments (δ_A and δ_B) associated with each factor. Data collected by observers in the Azores fishery during May-December 1998 (151 observed sets) indicate a mean take rate of 0.19 turtles per 1,000 hooks under current conditions. In keeping with the design assumption above, this take rate is therefore regarded as an estimate of $\mu_{2.}$ and μ. For simplicity, it was also assumed that $\delta_A = \delta_B = \delta$. Further, the increment δ was expressed as a fraction of the current mean take rate: $\delta = \gamma\mu_{2.}$ where the parameter γ ranges from 0 up to a maximum value dependent on the design. In the Azores design, γ has a maximum value of 2/3. Using these relationships, the mean take rate under base conditions (μ_{11}) can be computed for any feasible combination of $\mu_{2.}$ and γ. Values of the other cell means follow readily from the design assumptions and constraints.

(3) Sampling variance refers to the variance in turtle takes at the scale of the sampling unit, i.e., per 24-hook basket. A related measure of variability for which estimates are more readily available is the variance in mean turtle take per 1,000 hooks as computed among sets; this is proportional to the variability in take rate among baskets. It is convenient to specify the level of variability in terms of the parameter ω, the ratio of the variance in take per 1,000 hooks at the set level to the mean take rate. In the Azores fishery, the observer data indicate that $\omega = 0.95$, i.e., the number of takes per 1,000 hooks at the set level is approximately a Poisson variate ($\omega = 1.0$). The information about take rate variability under current conditions, combined with other assumptions (e.g., how the mean and variance of take rate are related; see below) allows us to compute average rate variability for the entire experiment.

(4) Type I error in the F tests was set at 5% (i.e., $\alpha = 0.05$).

Computational Method

Power was estimated for several combinations of $\mu_{2.}$ and γ, with $\mu_{2.}$ ranging from 0.2 to 2.0 and γ from 0.1 to the maximum value of 0.67 (Tables 1 and 2). The lowest value of $\mu_{2.}$ considered is 5-10 times lower than the mean take rate reported at the 1998 Horta planning meeting (the latter figure was apparently based on summary information from a couple of observer trips).

Power was estimated by simulating the longline experiment 500 times under each set of conditions, conducting the appropriate ANOVA F tests, and observing the proportion of times

$_AH_0$ and $_BH_0$ were rejected under the specified alternative hypotheses. Take data for each basket in an experiment were generated from a stochastic model of the take process parameterized with the appropriate take rate distribution. The model invented for this purpose was a 2-stage Bernoulli-Poisson mixture model. This model assumes that each basket of hooks deployed has a specified probability β of not encountering turtles at all, e.g., due to patchiness of the turtle distribution; in this event none are taken. If a basket does encounter turtles (with probability 1 - β) the number of turtles taken (including possibly 0) is Poisson with a specified mean take rate. The β parameter was estimated from the current take rate conditions, and a Poisson parameter was computed for each cell of the design based on the value of β and the expected take rate in the cell. For purposes of the simulation, the minimum value of ω at the basket level was set at 1.01 (i.e., take rates were always over-dispersed). This is just slightly greater than the variance indicated by the observer program data. Likewise, the minimum take rate considered was 0.2, slightly higher than the estimated current conditions.

Power estimates derived from the simulations were checked against the power curves published by Pearson and Hartley (Biometrika, Vol. 38, 1951, p. 112) and reprinted in various other references. These curves are based on the non-central F distribution. The non-centrality parameters required to use the power charts were calculated in each simulation as a function of the sample size, overall variance, proportional effect, and other parameters. In each case, comparisons of simulation results with charted values showed the simulation results to be accurate.

Results

Results are given in Tables 1 and 2. The first row in each table is for $\mu_{2.}$ = 0.2, roughly the current conditions in the fishery. In this case reasonable power levels (say, > 80%) with respect to $_AH_0$ cannot be achieved under the design constraints assumed (Table 1). Tests of $_BH_0$ are even less powerful than those for $_AH_0$, for effects of the same magnitude (Table 2).

In the second row of results, which assume $\mu_{2.}$ = 0.5, power is greater but differences between marginal means of the A-factor will need to be 60% or greater for reasonably powerful tests of $_AH_{0.}$ Tests of $_BH_0$ are still not possible with sufficient power.

With $\mu_{2.}$ = 1.0, there is sufficient power to detect differences between marginal means of the A-factor greater than about 40% and differences among marginal means of the B-factor greater than about 60%.

With $\mu_{2.}$ = 2.0, there is sufficient power to detect differences between marginal means of the A-factor greater than about 30% and differences among marginal means of the B-factor greater than about 45%.

Comments

(1) Power would be increased by accepting a higher level of Type I error (say α = 0.10), but I have not computed these cases.

(2) Other things remaining equal, the power of the F tests can be increased by dropping one of the experimental factors, resulting in a single-factor experiment with the same total sample size, or to increase the sample size, e.g., by increasing the number of sets. For example, with a proportional difference of $\gamma = 0.5$ in a single-factor experiment studying factor A at 3 levels, the F test would have a power of about 80% when the current mean take rate is 0.5 turtles per 1,000 hooks. Under the 2-factor design, the power is only 65% (Table 1).

(3) Here it was assumed that the response variable was simply the number of turtles taken in a basket. For treatments like hook type, however, the appropriate variable may be more complex, e.g., involving not only take rate but some score related to severity of injuries sustained in the hooking, etc. How should this be handled?

Table 1. Approximate power of F test for detecting proportional differences in the mean take rate of turtles (γ) between 3 hook types given assumed current mean take rate (turtles per 1,000 hooks, $\mu_{2.}$). Assumes $\alpha = 0.05$ and $\omega = 1.01$.

$\mu_{2.}$	γ						
	0.1	0.2	0.3	0.4	0.5	0.6	0.67
0.2	<0.30	<0.30	<0.30	<0.30	0.32	0.38	0.46
0.5	<0.30	<0.35	0.31	0.43	0.65	0.79	0.88
1.0	<0.30	0.30	0.47	0.75	0.91	0.98	>0.99
2.0	<0.30	0.43	0.79	0.96	>0.99	>0.99	>0.99