

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

This technical memorandum series is used for documentation and timely communication of preliminary results, interim reports, or similar special-purpose information. Although the memoranda are not subject to complete formal review, editorial control, or detailed editing, they are expected to reflect sound professional work. The views and conclusions expressed by the authors are not necessarily those of the National Marine Fisheries Service. In addition, the mention of trade names or commercial firms is for information only and does not imply endorsement by the National Marine Fisheries Service.

This report was prepared in fulfillment of reference order 40AANF804175 issued to the Archie Carr Center for Sea Turtle Research.

Suggested Citation:

Bolten, A. B., H. R. Martins, and K. A. Bjorndal, editors. 2000. Workshop to design an experiment to determine the effects of longline gear modification on sea turtle bycatch rates. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-19, 50 p.

Copies of this report may be obtained from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161 USA

(703) 487-4650
(800) 336-4700 (rush orders)

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

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

**NOAA Technical Memorandum
NMFS-OPR-19
December 2000**



U.S. Department of Commerce
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

Table of Contents

Acknowledgments	v
Workshop Agenda	vi
Workshop Participants	x
Opening Remarks (<i>Abertura</i>)	
Helen R. Martins	1
The Swordfish Fishery in the Azores: an Overview	
Alexandre Aires da Silva	3
Information on Accidental Capture of Marine Turtles in the Azores <i>(Informação disponível sobre a pesca accidental de tartarugas nos Açores)</i>	
Manuel F. Serpa	17
Turtle Bycatch Study in the Longline Fisheries of the Azores	
R. Prieto, R. Ferreira, and A. Silva	22
Observation Program for Fisheries in the Azores (POPA): Aspects Related to Marine Turtles <i>(Programa de Observação para as Pescas dos Açores (POPA):</i> <i>Aspectos relacionados com Tartarugas Marinhas)</i>	
Rogério Feio	29
Approach to the Experimental Design and Review of the Experimental Variables with the Objective of Stimulating Discussion <i>(Aproximação ao desenho experimental e revisão das variáveis experimentais,</i> <i>com o objectivo de estimular a discussão)</i>	
Eduardo Isidro and Mário Pinho	32
Experiment to Evaluate Gear Modification on Rates of Sea Turtle Bycatch in the Swordfish Longline Fishery	40
Statistical Power of the Azores Longline Experiment	
Jerry A. Wetherall	44
Closing Remarks (<i>Comentários de encerramento</i>)	
Helen R. Martins	50

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 análise.

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 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 há 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 répteis muito antigos. Já existiam nos mares há 100 milhões de anos, viviam no tempo dos dinossaúros, 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 Migratórias 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 (CDB₁) and large size cabin-deck boats (CDB₂). 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; CDB₁: small-size cabin-deck boats; CDB₂: 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 (CDB₁; 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 CDB₁ has declined continuously to 26 in 1998.

Large-size cabin-deck boats fishing for swordfish throughout the year represent the third Azorean fleet component (CDB₂; 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 CDB₂ 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 CDB₂ 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 36-48° N, 18°-42° 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 asynchronous 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 asynchronous 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.

Literature Cited

- Fernandes, L. 1987. Pesca Experimental de espadarte nos Açores com Palangre de deriva. *VII Semana das Pescas dos Açores* 1987: 121-126
- Fleming, E. H. and P. A. Papageorgiou. 1997. Shark fisheries and trade in Europe. TRAFFIC Europe, Brussels, Belgium. 78 p.
- Pereira, J. 1988. La pecherie de l'espadon aux Açores. ICATT, *Coll. Vol. Sci. Papers* SCRS/87/85, Vol. XXVII (2): 318-320.
- Pousa, A. G. 1987. Como se trabalha al espadarte. *VI Semana das Pescas dos Açores* 1986: 269-271.
- Silva, H. M., A. A. Silva & P. Simões. 1996. Relatório do cruzeiro de grandes pelágicos realizado durante o Outono 93/Primavera 94 nos Açores (ARQPAÇO-01-O93/P94). *Arquivos do DOP, Série Cruzeiros*, 1 (1996). ISSN 0873-2876.
- Simões, P. and H. M. Silva. 1994. Caracterização da pesca de espadarte (*Xiphias gladius*) em águas Açoreanas: período 1987-92. *XIII Semana das Pescas dos Açores* 1994:203-222.
- Simões, P. 1995. The swordfish (*Xiphias gladius* L. 1758) fishery in the Azores, from 1987 to 1993. ICCAT, *Coll. Vol. Sci. Papers* SCRS/94/109, Vol. XVIV (3): 126-131.



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



**Figure 1. Components of the longline fleet fishing for swordfish in the Azores:
B - Azorean small-size cabin-deck boats (CDB₁);**



**Figure 1. Components of the longline fleet fishing for swordfish in the Azores:
C - large-size cabin-deck boats from the Azores and Mainland Portugal (CDB₂;
MPB)**

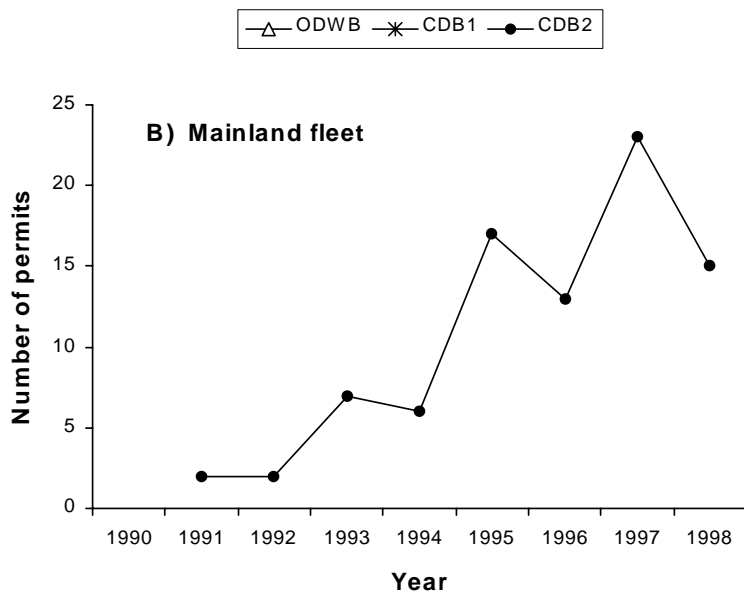
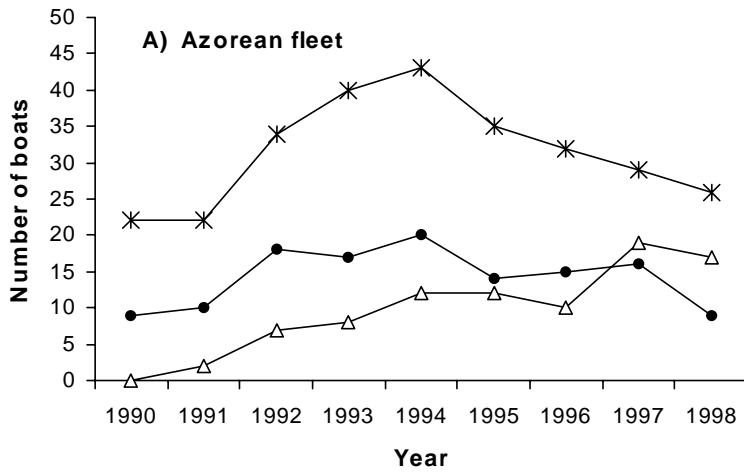


Figure 2. Number of fishing permits (=boats) for the longline fishery in the Azores, 1990-1998.

A - Azorean fleet (ODWB - open-deck wooden boats; CDB₁ - small size cabin-deck boats; CDB₂ - large-size cabin-deck boats).

B - Mainland Portugal fleet.

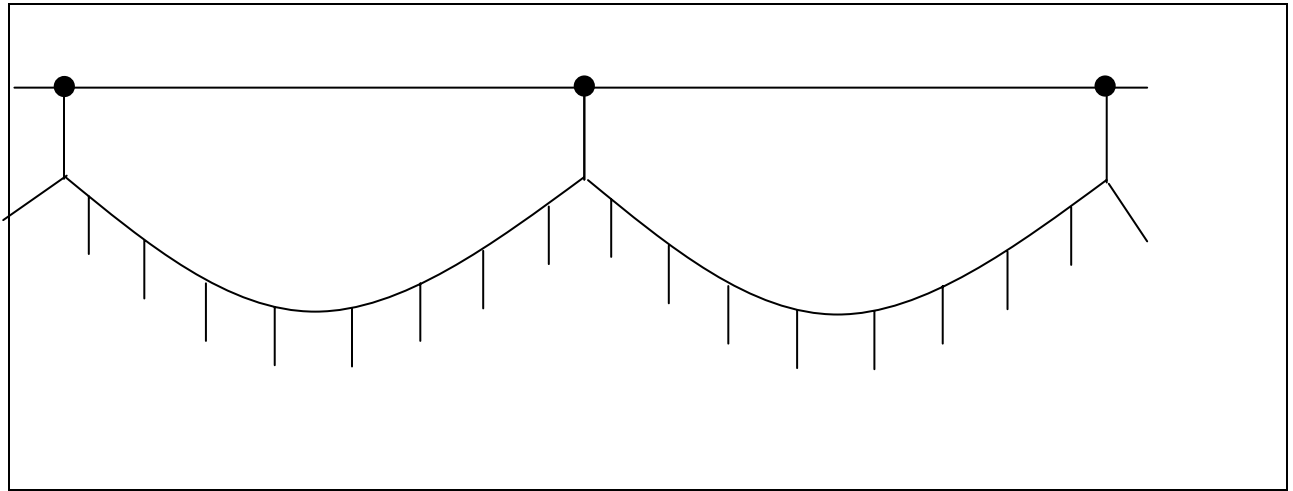


Figure 3. Longline gear.

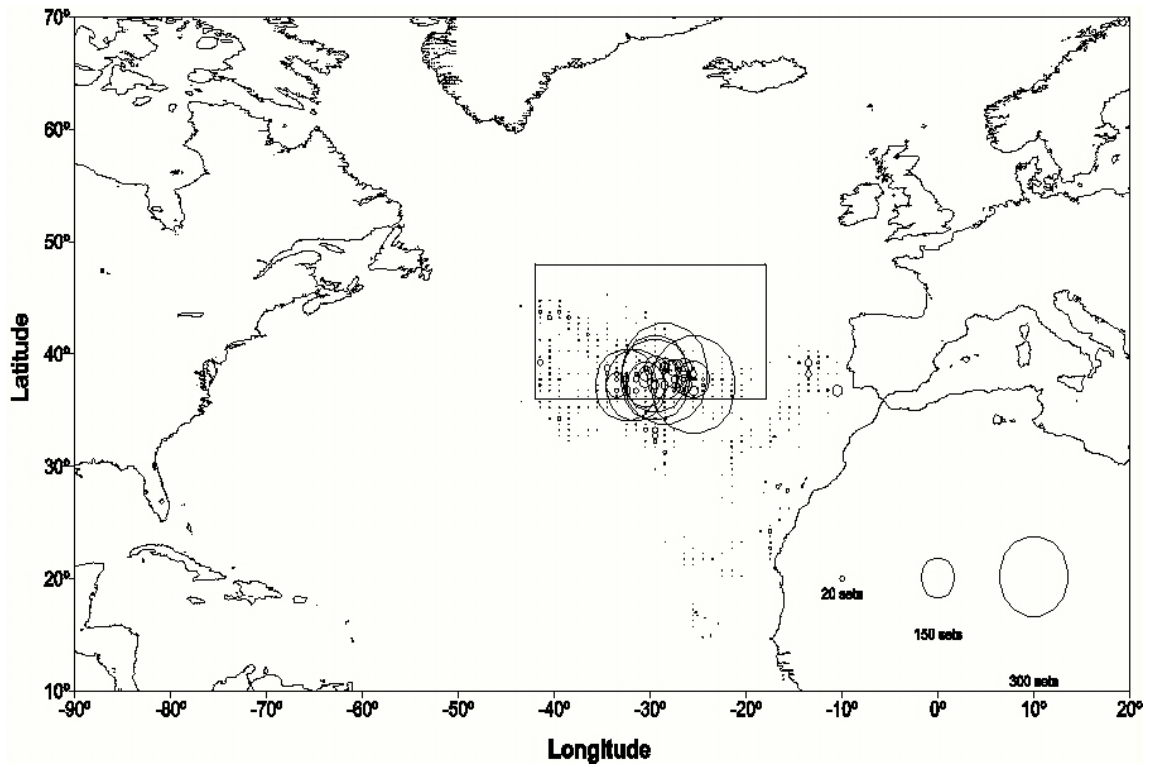


Figure 4. Longline sets reported in Portuguese fishing logbooks, 1993-1998. The rectangular area represents the ICES area X which contains most of the Azorean EEZ.

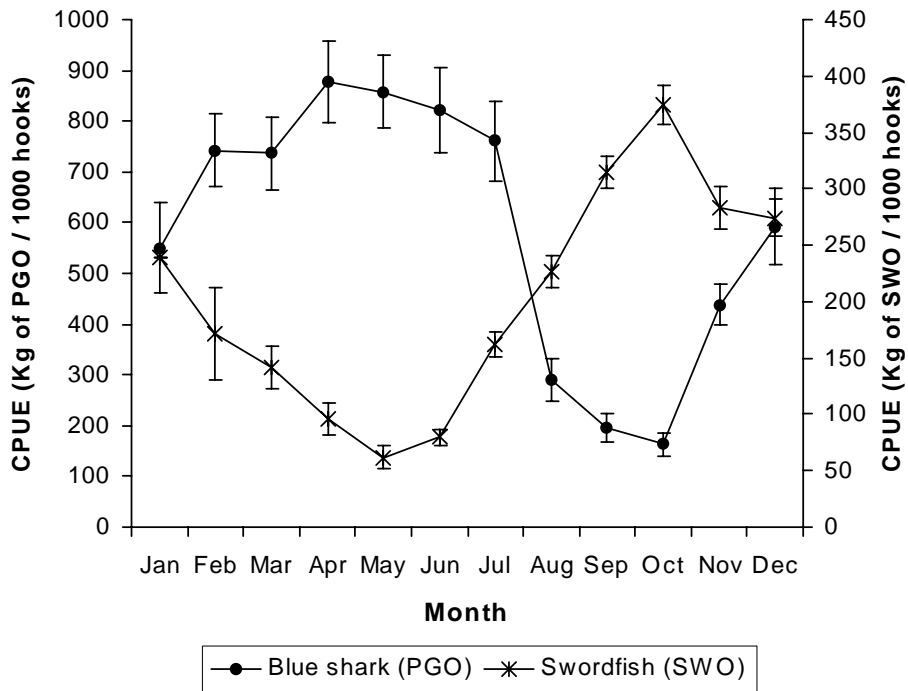


Figure 5. Monthly mean catch rates of swordfish (SWO) and blue shark (PGO) in the Azores, 1993-1998. Vertical lines represent 95% confidence intervals of the mean estimates.

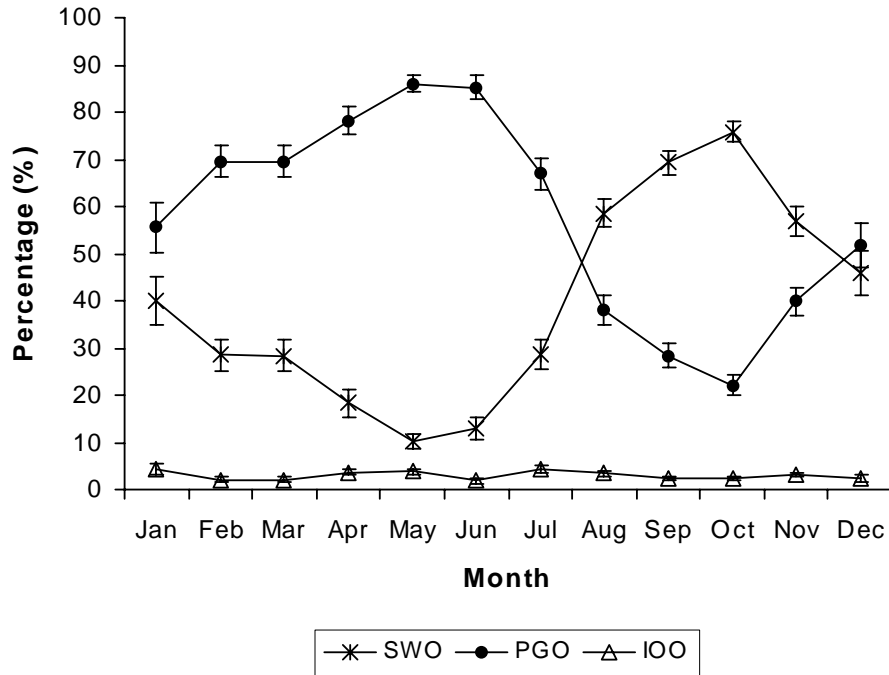


Figure 6. Monthly mean catch proportions of swordfish (SWO), blue shark (PGO) and shortfin mako (IOO). Vertical lines represent 95% confidence intervals of the mean estimates.

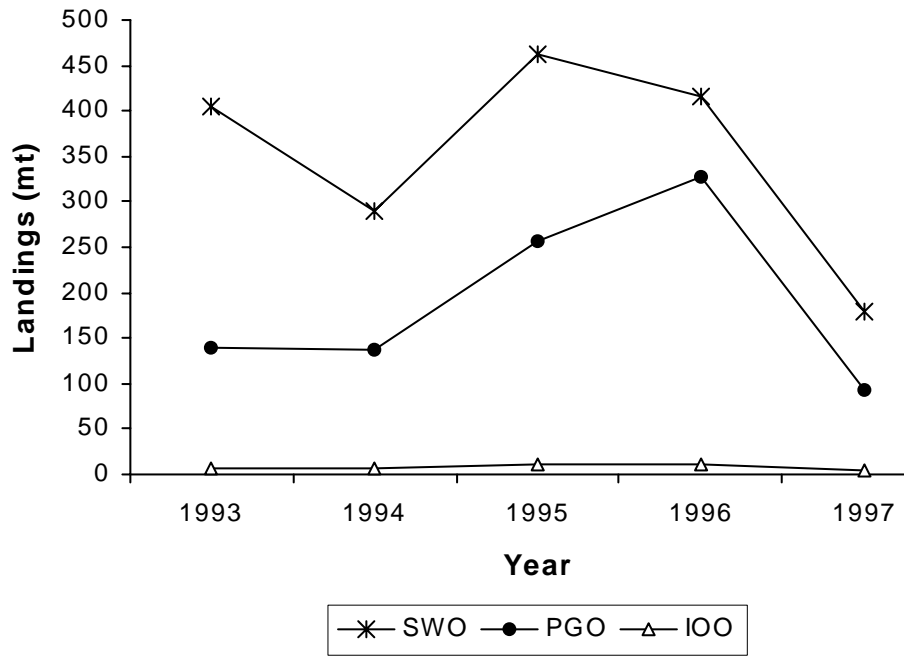


Figure 7. Yearly landings (metric tons) of swordfish (SWO), blue shark (PGO) and shortfin mako (IOO) in the Azores, 1993-1997.

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 (15° to 16° 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.

Informação disponível sobre a pesca acidental de tartarugas nos Açores

Infelizmente pouco ou nada existe de informação registado em qualquer organismo oficial, no entanto e dentro do possível, tentarei dar alguns registos pessoais, outros através de diálogos com mestres de outras embarcações e também através da assistência de algumas descargas.

Irei começar por capturas recentes em duas embarcações no ano de 1996, visto ser aquelas que tenho um registo mais concreto:

Em Setembro e Outubro no palangreiro 'S.Miguel', capturou-se cerca de 100 tartarugas em 22 lances, 15 deles junto às ilhas dos grupos Oriental e Central e nalguns bancos; os restantes 7 lances foram efectuados mais distantes, mais precisamente no Banco Voador, Banco Sarda e um no Banco Gigante. Nos primeiros 15 lances foram capturadas cerca de 90% de tartarugas com maior incidência no Mar de Prata, ilha de S. Miguel e Baixo de S. Mateus, ilha do Pico. As capturas foram de 10 toneladas de espadarte, 12 toneladas de tubarão, 0.5 tonelada de atum e cerca de 100 tartarugas careta como já mencionado. A temperatura das águas variou de 20-22 graus Celsius. A média de anzóis foi de 1000. O isco variou em 75% cavala e 25% lula.

Em Novembro e parte de Dezembro, o palangreiro polivalente Mar de Cristal, capturou cerca de 40 tartarugas em 16 lances, todos eles junto aos Bancos de S. Mateus, Banco de Açor e Mata de Prata. Dois deles foram efectuados junto à ilha de S. Miguel. As tartarugas foram capturadas na maioria no mês de Novembro e junto ao Baixo de S. Mateus, tendo-se capturado 6 exemplares num só dia. Capturou-se na totalidade 8 toneladas de espadarte, 6 toneladas tubarão, 300 kg de atum patudo e cerca de 40 tartarugas careta como acima mencionado. As tartarugas em média tinham um peso de 30 kg, a média de anzóis por lance foi de 900. O isco foi em percentagem de 75% de cavala, 15% de lula e 10% de filete de tubarão. O número de embarcações na zona variava de 2 a 4.

Posso desde já mencionar que nos meses de Julho e Agosto encontrámos indivíduos de vários pesos e comprimentos, a partir de Setembro já encontrámos indivíduos mais seleccionados e com maior peso. Poderá isto significar que os indivíduos mais pequenos atravessam as nossas águas nos meses mais quentes, mais concretamente em Julho e parte de Agosto.

Numa outra experiência minha, a bordo de um atuneiro palangreiro japonês, nos meses de Março e Abril de 1991 nos mares dos Açores, onde obtivemos alguns exemplares não representativos, na ordem de 3 a 5 exemplares, sendo dois deles tartarugas de couro. O número reduzido de exemplares poderá estar relacionado com dois factores: a temperatura reduzida que variou à superfície entre 15 e 16 graus e também pelo facto da pesca ser dirigida ao atum rabilo, ou seja, feita a grandes profundidades, ficando o longline a uma média de 80 metros de profundidade.

Ainda outra experiência foi levada a cabo, a bordo de um palangreiro dinamarquês/canadiano 'IMAQ FISH', dirigida ao atum rabilo. A campanha teve início em Junho de 1990 tendo terminado em Setembro do mesmo ano, esta campanha foi efectuada por mim e por outro

colega, tendo sido iniciada nos mares dos Açores até à costa do Canadá. Em virtude das capturas baixas em tunídeos e de ocorrência de grandes quantidades de espadarte, alterou-se o palangre, dirigindo-se apenas para esta espécie.

Nesta campanha, capturou-se vários exemplares de tartarugas, mais precisamente, nos meses de Junho e Julho, sendo estes sempre recolhidos nos anzóis junto das bóias.

Nos finais de Julho, quando nos afastámos para WNW da ilha das Flores, surgiram sempre alguns indivíduos de grande porte (entre 20/30 kg). No entanto, à medida que subíamos para Norte a cerca de trezentas milhas do Grand Bank, deixámos de capturar qualquer exemplar.

As capturas dos 30 lances foram de 4 patudo (bigeye), 7 galha-à-ré (yellowfin), 9 rabilo (bluefin), 38 tintureira (blue shark), 39 espadarte (swordfish), 20 tartarugas careta (*Caretta caretta*) e 3 tartarugas de couro (*Dermochelys coriacea*). Com a mesma embarcação fez-se ainda uma experiência ao espadarte, no mês de Novembro, resultante do número de espécies capturadas na experiência anterior e dos maus resultados em espécies de tunídeos. Embora a época propícia já tivesse passado, ainda capturou-se 11 exemplares de tartarugas careta (*Caretta caretta*), 3 tartarugas de couro (*Dermochelys coriacea*) tendo uma delas pesado 415 kg; a pesca foi feita mais à superfície e as temperaturas das águas mantiveram-se entre os 19 e 18 graus Celsius. Em resumo, as capturas totais foram de 2 rabilo, 1 patudo, 2 galha-à-ré, 1 voador, 3 tintureiras, 4 rinquim, 104 espadartes, 11 tartarugas (8 tartaruga careta e 3 tartarugas de couro).

Campanha de atum com palangre na embarcação 'António Duarte'. Esta experiência foi levada a cabo nos meses de Novembro e Dezembro de 1989 e Janeiro e Fevereiro de 1990, tendo como objectivo o atum de Inverno. Em 32 lances efectuados, capturou-se 910 tintureira, 114 espadarte, 3 patudo, 2 voador, 8 rinquim, 3 tartarugas de couro e 2 tartarugas careta. O pequeno número de tartarugas capturadas deveu-se à época do ano e também ao palangre ser dirigido ao atum, ficando este a maior profundidade.

Em resumo, poder-se-á concluir que as tartarugas incidem mais nos meses de Junho, Julho e parte de Agosto, capturando-se mais indivíduos quando a pesca é dirigida a espadarte. Verificou-se que a maior parte dos indivíduos são capturados nos anzóis junto às bóias. Nas minhas experiências verifiquei de que à medida que o Verão avançava, os indivíduos eram na sua maioria de grande porte e poucos se avistavam à superfície. Ainda fiquei com a ideia de que, nos fins de Agosto até meados de Setembro, parece ser mais reduzido o número de tartarugas, surgindo novamente em Outubro e Novembro, em especial quando as condições climáticas são favoráveis.

Queria também salientar, que grande parte das tartarugas ou até mesmo a sua maioria, são rejeitadas ao mar pelos pescadores sem entrar no navio, muito em especial, nos palangreiros de maior profissionalismo e de grande porte. Na alagem do palangre, o tempo perdido com uma tartaruga bastaria, para recolher dois a três anzóis, daí não haver motivação para recolher para bordo as tartarugas, sendo na sua maior parte cortadas pelo estralho. Só raramente, quando as condições do estado do mar e a pescaria é favorável é que as tartarugas são desiscadas do anzol e largadas ao mar.

Posso adiantar com alguma segurança que, o número de tartarugas a desprenderem-se dos anzóis durante a alagem é quase insignificante, apenas poderá acontecer esporadicamente num

grande palangreiro a grande velocidade, na época de Inverno onde as condições do mar são muito desfavoráveis.

Posso concluir que em todas as campanhas efectuadas por mim, só uma vez foi registado a recolha de uma tartaruga sem vida e raramente outras vinham com aparência de cansaço e fraqueza.

Espero que, em discussão e diálogo possamos definir com maior rigor estas ideias assim como outras questões.

Turtle Bycatch Study in the Longline Fisheries of the Azores

R. Prieto, R. Ferreira, and A. Silva

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

Abstract

A study was conducted to try to quantify the bycatch of marine turtles by the longline fisheries in the Azores. The sampling method was designed to provide information about the fishery and associated bycatch as catch per unit effort and biological data on the turtles and other species caught accidentally, especially blue sharks. The mean capture for 1000 hooks per month varied between 0.036 and 0.753, respectively, in May and July, with the number of turtles captured per set between 0 and 7. Most of the turtles were hooked in the mouth. Of the 27 turtles captured, 19% were caught on hooks baited with mackerel, 11% with squid, and the remaining (70%) with unidentified bait. Only one of the 27 turtles was found dead. The data presented constitute the preliminary results from the study. We plan to put more observers on longline fishing boats during the coming months.

Introduction

During recent years there has been increasing concern regarding the accidental capture of turtles in longline fisheries as a threat to some populations. A few years ago this fishery was considered to cause little harm to turtle populations (Hillestad et al., 1995), but further studies on population dynamics and accounts from fishermen in some areas indicate otherwise. It is probable that the impact the fishery has on turtle populations varies with area and the different techniques used.

To better understand this impact and manage turtle populations affected by this fishery, it is critical to quantify the capture rates and compare the results from different areas and techniques to develop management strategies wherever necessary. The study presented here was designed to address this problem and to serve as a guideline in the design of more complex and broader studies.

Overview of Sea Turtle Biology in the Azores

In the Azores EEZ, loggerheads (*Caretta caretta*) constitute the overwhelming majority of marine turtles, whereas green turtles (*Chelonia mydas*) and leatherback turtles (*Dermochelys coriacea*) occur occasionally (Martins, pers. comm.). Studies of size distribution, tagging and recapture experiments (Carr, 1986; Bolten et al., 1993, 1995) and more recently of genetics (Bolten et al., 1998) show that the post-hatchling loggerheads from the east coast of North America are carried by the oceanic currents to the eastern Atlantic, through the Azores, Madeira,

Canary Islands, and perhaps the Cape Verde Islands. The movements of these turtles are probably associated with the North Atlantic Gyre System, and the duration of the pelagic stage is estimated to be between 10-12 years (Bolten et al., 1995).

The pelagic-stage loggerheads found around the Azores have curved carapace lengths varying between 10 and 60 cm, with a mean of 33.6 cm, and represent an early stage of the life history of the turtles nesting in the southeastern United States and Yucatan Peninsula. The loggerhead turtles frequenting the Azores waters are thus immature animals, which have a high probability of reaching maturity and are therefore very important to the maintenance of the population.

Study Design

The longline fishery in the Azores is supposed to be directed at swordfish (*Xiphias gladius*), but recent studies show that two main seasons occur, and the catch between February and June is composed mainly of blue sharks (*Prionace glauca*). Between June and December the catch is mostly composed of swordfish (see Silva in this volume). The gear can also differ, and two different set-ups are used which fish at distinct depths.

The study was designed to cover the two seasons, and efforts were made to sample the two set-ups. In order to carry out this study, some companies fishing in the Azores with longline gear were contacted, and they agreed to take onboard one observer to monitor the fishery. The sampling method was designed to provide information about the fishery and associated bycatch as catch per unit effort and biological data on the turtles and other species, especially blue sharks. Whenever a turtle was caught, the observer would stop any other work to record the data on the turtle and to attend to it, if necessary.

The data collected for turtles were:

1. Species
2. Measurement of the curved carapace length
3. Collection of skin sample for DNA analysis
4. Capture
 - Method of capture (hook or entanglement)
 - Condition (dead; weak; strong)
 - Position of hook or entanglement
 - Position of the hook in the digestive tract (if applicable)
5. Other pertinent observations

After the data were collected, the turtle was tagged and released, and observations were made on its behavior. In the case of a dead turtle, the right front flipper and stomach were frozen.

The first observer was put on the fishing boat "Altair" in May, and the sampling was made between May and August. The observer trained one of the fishermen, and during the months of June and July, this fisherman collected the data.

Preliminary Results

The data presented below constitute the preliminary results from the study and are presented only to give an idea of the benefits a program of observers could bring to the understanding of the sea turtle longline bycatch.

The size frequency of loggerhead turtles (*Caretta caretta*) caught in the swordfish fishery between May and August is presented in Figure 1. The mean capture for 1000 hooks per month varied between 0.036 and 0.753 (Figure 2), respectively, in May and July with the number of turtles captured per set between 0 and 7.

Of the 27 turtles captured, most of them (25) were hooked in the mouth; only one was hooked in the eye, and another in the flipper. Except for one turtle with a hook in the junction of the jaw that could not be removed, all of the turtles that were brought onto the boat were freed from hooks and lines. Only one of the 27 turtles was dead. In addition, the fishermen reported an undetermined number of turtles captured in June that were not hauled onto the boat due to their large size (two of them were leatherback turtles, and the others were loggerheads). These turtles were set free by cutting the line attached to the hook and thus the position of the hook is not known.

The relation between capture and the baits used is presented in Figure 3. Of the 27 turtles captured, 19% were caught on hooks baited with mackerel, 11% with squid, and the remaining (70%) with unidentified bait.

Conclusions

The results of this study are preliminary, and we intend to put more observers on longline fishing boats during the coming months. It is, thus, too soon to draw any conclusions about the bycatch of marine turtles around the Azores in this fishery. Nonetheless, we believe that as data are collected in this way, there will be a better understanding of the magnitude of the bycatch, as well as of the way in which it occurs. In addition, information on other species can also be gathered in this way and can help in the management of the fishery.

The work achieved during this first phase was not only encouraging scientifically. It also showed that a close collaboration with the fishermen could produce good results regarding the conservation of turtles. The fishermen on "Altair" and the owner of the company were very receptive to the study and even eager to learn how they could help the turtles. It is reasonable to think that more fishermen and companies would be receptive not only to have other observers onboard, but also, in some cases, to try alternative techniques to reduce the bycatch, if this is proved to be necessary.

Literature Cited

Bolten, A. B., K. A. Bjorndal, H. R. Martins, T. Dellinger, M. J. Biscoito, S. E. Encalada, and B. W. Bowen. 1998. Transatlantic developmental migrations of loggerhead sea turtles demonstrated by mtDNA sequence analysis. *Ecological Applications* 8:1-7.

- Bolten, A. B., K. A. Bjorndal, and H. R. Martins. 1995. Life history of the loggerhead sea turtle, *Caretta caretta*, (Reptilia: Cheloniidae), in the Atlantic. Bol. Mus. Mun. Funchal 4:115-122.
- Bolten, A. B., H. R. Martins, K. A. Bjorndal, and J. Gordon. 1993. Size distribution of pelagic-stage loggerhead sea turtles (*Caretta caretta*) in the waters around the Azores and Madeira. Arquipélago 11A:49-54.
- Carr, A. 1986. Rips, FADs, and little loggerheads. BioScience 36:92:-100.
- Hillestad, H. O., J. I. Richardson, C. McVea, Jr., and J. M. Watson, Jr. 1995. Worldwide incidental capture of sea turtles. Pages 189-496 in K. A. Bjorndal, editor. Biology and Conservation of Sea Turtles, revised edition. Smithsonian Institution Press, Washington, D.C., USA.

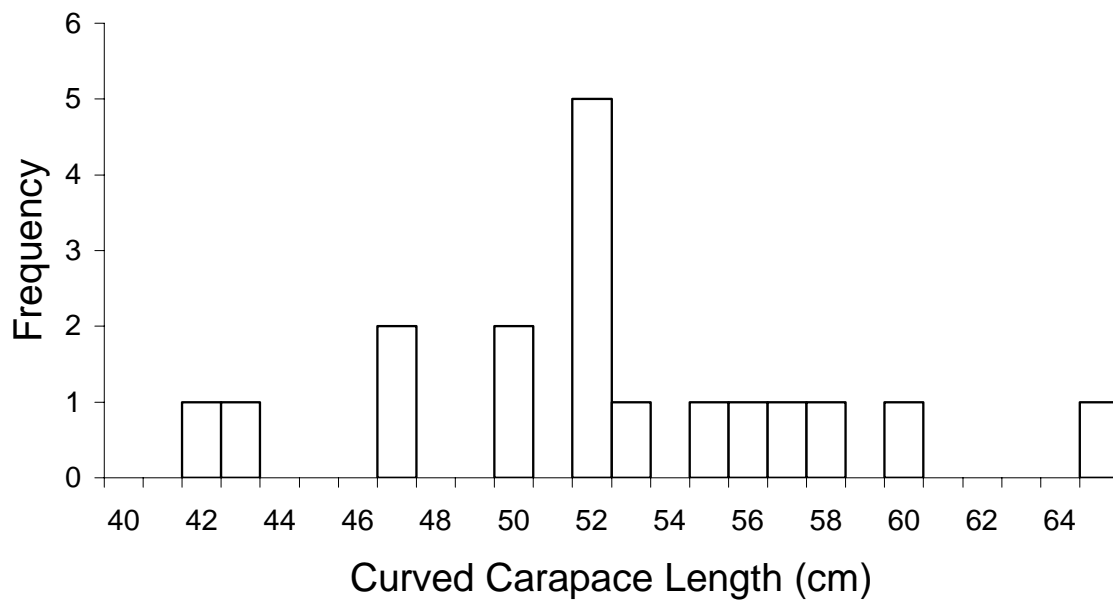


Figure 1: Size distribution of loggerheads (n = 18) captured by longline fisheries around the Azores.

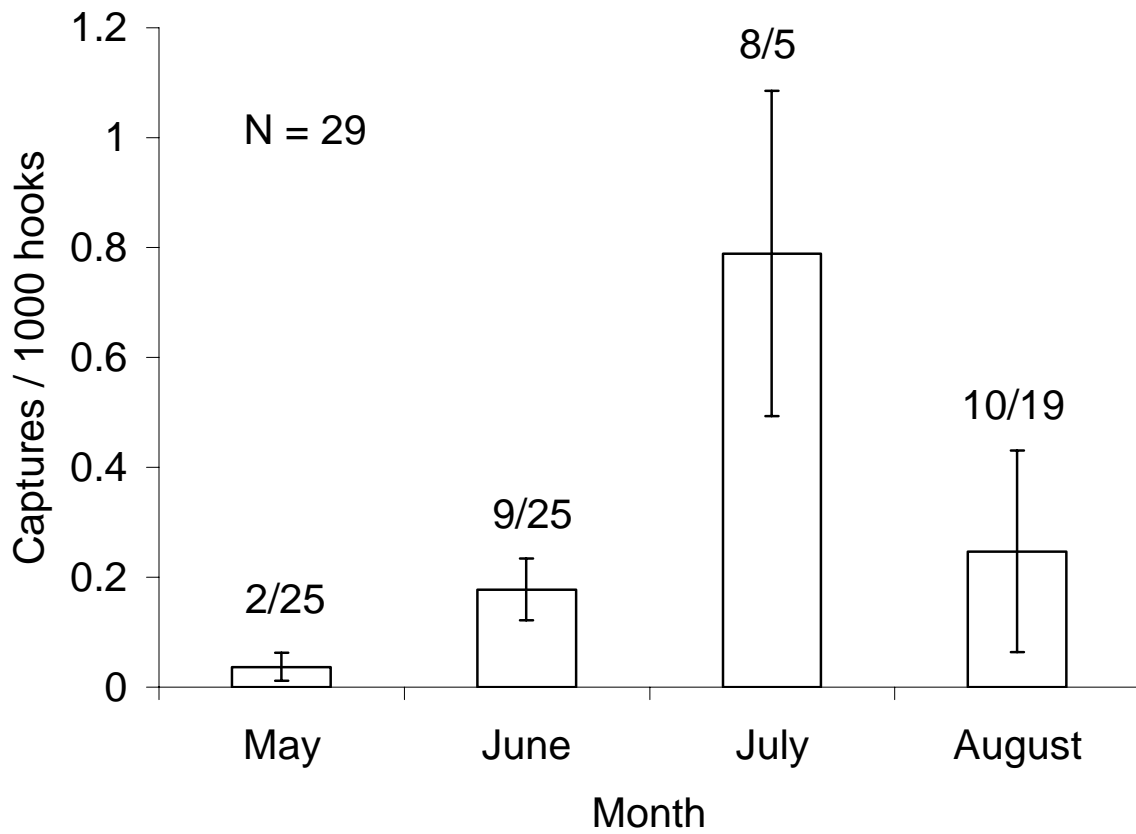


Figure 2. Mean capture of loggerhead sea turtles in longline fisheries around the Azores. Fractions above the bars represent the number of turtles caught per number of sets. Error lines represent the error at a confidence level of 0.95.

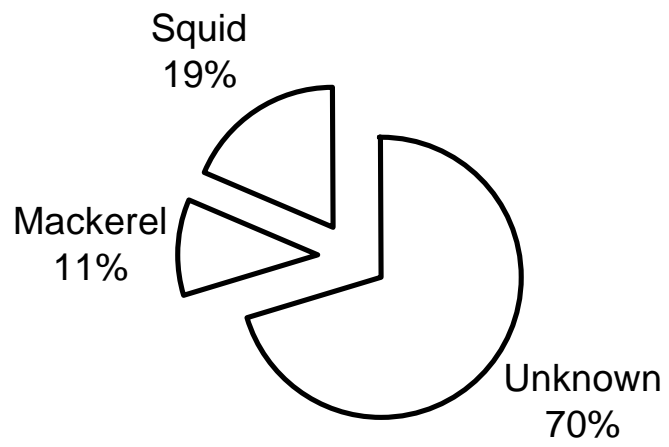


Figure 3: Distribution of bait type for loggerhead turtles captured in the longline fishery around the Azores.

**Observation Program for Fisheries in the Azores (POPA):
Aspects Related to Marine Turtles**

***Programa de Observação para as Pescas dos Açores (POPA)
Aspectos relacionados com Tartarugas Marinhas***

Rogério Feio

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

English Summary

As part of the Observer Program for the Fisheries of the Azores (POPA), information related to sightings and tagging of turtles is also collected. That information is recorded by the 10 observers contracted for POPA on the tuna fishing vessels. All of the data presented here are related to the sampling period between 15 May and 31 July 1998. One of the objectives of this work is to relate the turtle sightings to the environmental conditions (temperature, beaufort and visibility). The results revealed no significant relation between temperature and turtle abundance. There is a very significant relation between visibility and beaufort (state of the sea) and the number of turtle sightings. This relationship suggests that atmospheric conditions can interfere with the detection of turtles at sea and that better environmental conditions improves the detection by the observers. From a total of 390 sighted individuals, 50 were tagged, corresponding to 12.8%. The tagged individuals had a minimum curved carapace length of 17 cm, a maximum of 55 cm, and a mean of 33.5 cm.

O POPA é uma proposta apresentada pelo DOP/UA que permite, por um lado, conhecer de forma objectiva as suspeitas que recaem sobre os pescadores açorianos relativamente à captura ilegal de cetáceos e, por outro lado, recolher dados sobre as pescas e espécies marinhas açorianas.

O POPA surge como consequência final dos vários contactos entre as partes interessadas na implementação deste programa (Industria Conserveira -COFACO-, Associação de Armadores da Pesca do Atum e Similares dos Açores -APASA-, Departamento de Oceanografia e pescas da Universidade dos Açores -DOP/UA-, “Earth Island Institute”, Serviço Açoreano de Lotas -LOTAÇOR-, “University of Hawaii” e a conserveira “Starkist Seafood”), com o patrocínio da Direcção Regional das Pescas dos Açores. Estes contactos surgiram como consequência do acordo de princípios em que estas entidades reconhecem que o POPA possa ser organizado e gerido pelo Centro do IMAR - Instituto do Mar da Universidade dos Açores (DOP/UA), de modo a poder contribuir para a atribuição do estatuto “dolphin safe” ao atum capturado nos Açores.

O objectivo fulcral do POPA, tendo por base uma inegável qualidade científica, é o de assegurar que não haja mortalidade intencional nem perseguição deliberada de cetáceos pelas tripulações das embarcações atuneiras. Este objectivo será assegurado pela presença de observadores embarcados nos navios atuneiros. Aproveitando este facto, pretende-se obter complementarmente dados científicos sobre cetáceos e outras espécies marinhas (caso das tartarugas e aves marinhas), bem como sobre a pescaria (capturas, esforço de pesca, preenchimento de diários de bordo, etc.).

No decorrer das campanhas de observação os 10 observadores contratados para o POPA, recolheram informação relacionada com avistamentos e marcação de TARTARUGAS. Os resultados obtidos são consequência de uma primeira abordagem estatística resultante da base de dados do POPA ainda em desenvolvimento. Esta fase do trabalho corresponde a uma abordagem preliminar que relaciona os avistamentos de tartarugas com as condições ambientais do meio (temperatura, beaufort e visibilidade).

Os resultados demonstram uma relação significativa entre o estado do mar (Beaufort) e o número de tartarugas avistadas, $G = -0,40$; $p = 0,00$; $n = 74$ (figura 1). No caso da visibilidade vs o tartarugas avistadas verifica-se também uma relação significativa entre as variáveis, $G = -0,49$; $p = 0,00$; $n = 74$ (figura 2). Os resultados obtidos revelam que condições ambientais influenciam a detecção de tartarugas por parte do observador e sugerem que melhores condições ambientais favorecem essa detecção.

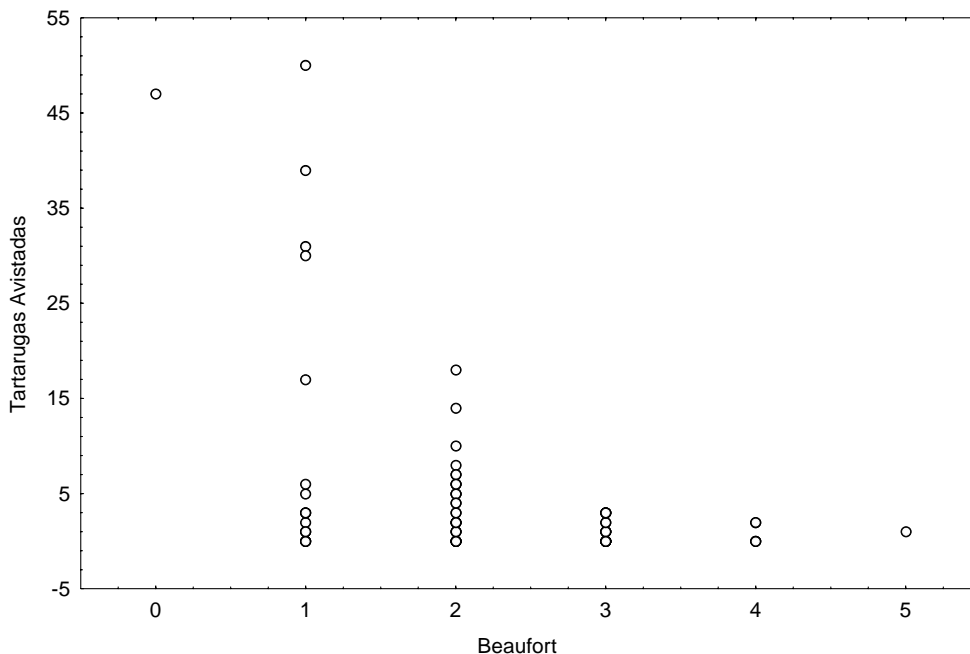


Figura 1 - Relação entre o Beaufort (estado do mar) e o número de tartarugas avistadas.

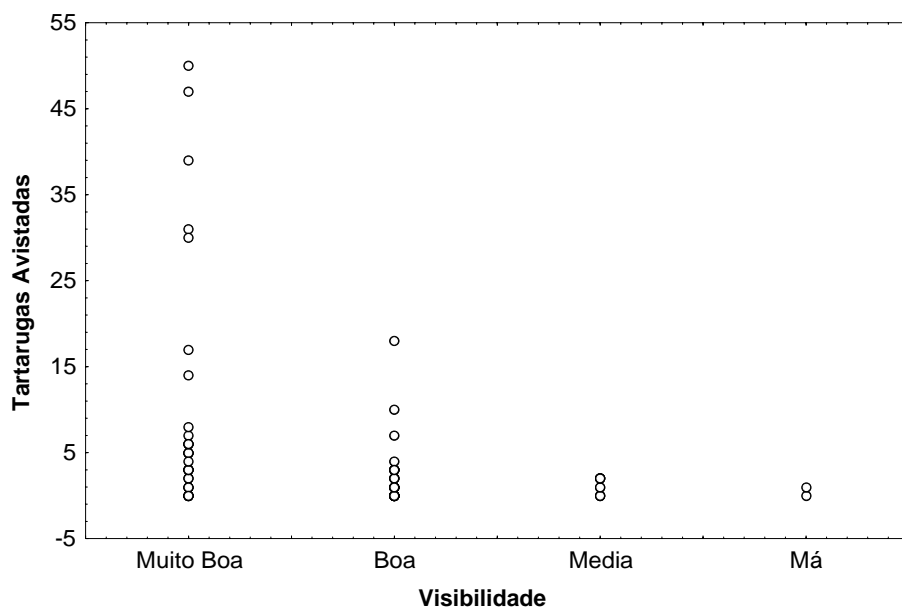


Figura 2 - Relação entre a visibilidade e o número de tartarugas avistadas.

No que diz respeito às classes de comprimento dos indivíduos marcados, os resultados revelam um comprimento médio da carapaça de 37,5 cm, tendo sido o comprimento máximo de 55 cm e o mínimo de 17 cm, para o total de 50 indivíduos marcados (figura 3).

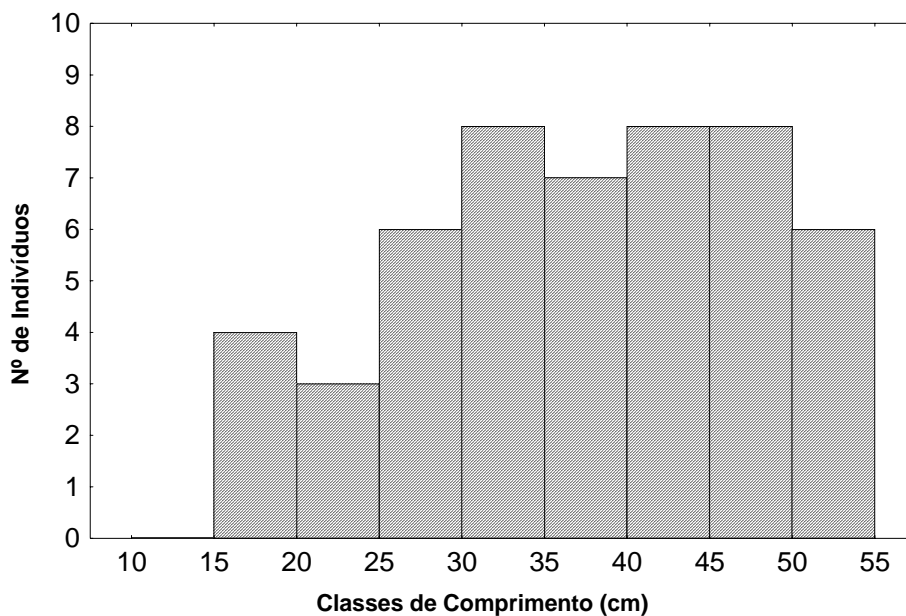


Figura 3 - Classes de comprimento das 50 tartarugas marcadas.

Approach to the Experimental Design and Review of the Experimental Variables with the Objective of Stimulating Discussion

*Aproximação ao desenho experimental e revisão das variáveis experimentais,
com o objectivo de estimular a discussão*

Eduardo Isidro and Mário Pinho

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

English Summary

The loggerhead sea turtle, *Caretta caretta*, comprises a part of the bycatch of the swordfish longline fishery. The available information on this fishery and respective bycatch is scarce. Thus, it is difficult at this point to elaborate a clear sampling and experimental design. The objective of this presentation is to perform a brief review of hook fishing aspects and selectivity properties, as well as to summarize the main experimental variables and the possible types of the experiments to compare them. As any experiment has its own set of assumptions and difficulties, at the end, two types of experiments will be discussed – experiments in captivity and experimental fishing – with the objective of stimulating further discussion.

Sumário

A tartaruga *Caretta caretta* é capturada acidentalmente na pesca de palangre do espadarte. A informação estatística e biológica disponível, não permite, nesta altura, elaborar um desenho experimental claro. O objectivo desta apresentação é o de rever brevemente os aspectos da pesca com anzol e as suas características selectivas, assim como o de rever as principais variáveis experimentais e o tipo de experiências que se podem fazer para as testar. Como cada experiência tem os seus pressupostos e dificuldades, submete-se à discussão, no final e com o objectivo de estimular a discussão, dois tipos de experiências: experiências em cativeiro e pesca experimental.

Introdução

O método científico consiste em analisar o problema, formular uma ou mais hipóteses, testar essas hipóteses através de experiência(s) cujos resultados, após tratamento matemático ou estatístico, conduzam à rejeição ou aceitação das hipóteses iniciais. Qualquer exercício de desenho experimental está, assim, dependente do problema e das hipóteses levantadas, e tentará, à priori, responder a três tipos de questões: Como recolher a informação necessária para testar a hipótese, onde e quando recolher essa informação e quantas amostras serão necessárias (Krebs, 1989).

Tipo de experiências

Uma forma simples de classificar as experiências consiste em dividi-las em dois grandes grupos - manipuláveis e observacionais (Scheiner & Gurevitch, 1993) - sendo óbvio que esta classificação é muito artificial e que a maior parte das experiências caem necessariamente entre estes dois tipos opostos (ver fig. 1).

Tomando a pesca comercial como uma experiência, uma vez que ela é uma fonte de dados cuja análise poderá servir para encontrar padrões temporais e espaciais correlacionáveis quer com a biologia das espécies quer com a estratégia ou com o regime de pesca, tudo o que se pode dizer é que dificilmente poderá responder ao problema posto neste "workshop" - desenho de uma experiência com o objectivo de determinar o efeito de algumas modificações no palangre de meia água, utilizado na pesca do espadarte, de forma a diminuir a captura accidental de tartarugas - mas que, todavia, deve ser compreendida em detalhe. A informação existente sobre a pescaria do espadarte e sobre as respectivas capturas accidentais, nomeadamente as de tartaruga, é muito escassa, e pouco ajuda na elaboração de um desenho experimental. Apesar disso, a análise prévia das capturas da pesca do espadarte (ver Silva, neste volume) já responde à pergunta de quando se deve fazer uma pesca experimental nos Açores. A resposta é, obviamente, na altura em que a captura accidental de tartarugas é maior, i.e., entre Junho e Outubro.

Convém, nesta altura, salientar que o problema que se está a analisar neste workshop é bastante complexo e que uma revisão da bibliografia sobre a selectividade do anzol mostra que este assunto ainda não está bem resolvido (ver McCracken, 1963; Pope et al., 1975; Ralston, 1982; Morais, 1990; Lokkeborg & Bjordal, 1992; Kenchington, 1993; Otway & Craig, 1993; Erzini et al., 1995, 1997; Millar, 1995; Sousa, 1996; Sousa et al., in press). De facto, caso se opte por uma pesca experimental, há que entender que há muitos factores em jogo, alguns difíceis de controlar e medir (e.g. interacções inter/intra específicas, comportamento perante a arte, factores ambientais, etc.), que podem aumentar de tal forma a variabilidade das capturas que só uma amostragem enorme poderá tornar o efeito dos tratamentos estatisticamente detectáveis. Isto significa que, com o conhecimento disponível, é difícil prever quanto tempo ou quantos lances ou quantas amostras serão necessárias para que, através de uma pesca experimental, se obtenha a informação suficiente para testar o efeito de determinadas variáveis. Significa também que, neste caso, é aconselhável testar um número reduzido de factores ou variáveis e recolher o maior número possível de amostras (executar um número elevado de lances).

Considerando o que se disse no parágrafo anterior, não se deve, por isso, esquecer as experiências em tanques ou gaiolas, uma vez que elas permitem controlar melhor uma série de factores adicionais, isolar os tratamentos e replicar experiências. No entanto, é de salientar que a execução deste tipo de experiências será sempre difícil nos Açores, por falta de locais naturais adequados (i.e. pouco expostos a uma acção intensa do mar, no caso das gaiolas), e que não há informação suficiente sobre o stress, e consequentes alterações comportamentais, induzido pelo cativeiro nas tartarugas. A alteração do comportamento dos animais em cativeiro é de facto o maior "handicap" deste tipo de experiências, levando, frequentemente, o investigador a preferir a pesca experimental.

Pesca com anzol e variáveis principais

Independentemente do tipo de arte de anzol utilizada, podem-se distinguir três etapas na captura com anzol: atracção, captura e escape (Bjordal, 1981). Em cada uma destas etapas, os factores ou variáveis que possivelmente terão maior influência e que são mais facilmente manipuláveis encontram-se sublinhados na tabela 1.

Conclusões

Nesta apresentação e nas apresentações anteriores, ficou claro que o conhecimento actual sobre a pesca do espadarte e sobre o "bycatch" de tartarugas é insuficiente quer nos Açores, quer noutras áreas de pesca, e que é importante que esta informação comece a ser recolhida num futuro próximo. Ficou também claro que as variáveis a testar, para responder ao problema posto neste workshop seriam: Tipo e tamanho de isco, tipo e tamanho de anzol, profundidade de pesca e tipo de estralho. O possível efeito de atracção das bóias foi também mencionado. Algumas destas variáveis, nomeadamente o tamanho do anzol e tipo de estralho, embora importantes na captura acidental de tartarugas, teriam certamente um impacto muito grande no rendimento da pesca do espadarte, pelo que quaisquer medidas baseadas no resultado desta experiência seriam difíceis de implementar. Sugere-se assim que estas variáveis não sejam testadas e que se focalize a atenção nas restantes variáveis. O tipo e tamanho de isco deve também merecer mais alguma reflexão como variável a analisar, uma vez que a *Caretta caretta* parece ter uma alimentação generalista (Preen, 1996) e que a alteração do isco também pode conduzir a alterações significativas nos rendimentos de pesca (ver e.g. Lokkeborg & Bjordal, 1993).

Como base para a discussão que se segue, apresenta-se um esquema de um palangre de meia-água, cujo desenho e características deverão ser definidas e completadas, tendo como objectivo a pesca experimental (Fig. 2), embora se insista que se debata previamente a possibilidade da realização de algumas experiências em cativo. Neste aparelho há ainda que prever a colocação de instrumentação para monitorizar o comportamento da arte (e.g. TDRs) e a sistematização da amostragem de forma a que a sua aplicação no campo seja tão simples quanto possível, que os dados resultantes sejam tratados como se o processo fosse verdadeiramente aleatório e que a informação recolhida seja tão completa quanto possível de forma a que se possa tirar algumas conclusões sobre a interacção entre as variáveis, o comportamento da espécie e alguns factores ambientais. Deve-se ainda acrescentar que, de acordo com as conclusões anteriores, a pesca experimental deverá ser feita entre Junho e Outubro, num local onde seja mais provável encontrar tartarugas e espadarte, com um aparelho de características idênticas, mas com uma dimensão ligeiramente menor que o utilizado na pesca comercial (i. e. com um menor número de anzóis, porque o processamento de pescado e informações a registar tornam a alagem mais morosa).

Bibliografia

Bjordal, A. 1981. Engineering and fish reaction aspects of longlining - a review. ICES C.M./B:35, 22 p.

Erzini, K., J. M. S. Gonçalves, L. Bentes, and P. G. Lino. 1995. Small hook longline selectivity study. Commission of the European Communities, DG XIV/C/1 ref. BIOECO/93/04.

- Erzini, K., J. M. S. Gonçalves, L. Bentes, and P. G. Lino. 1997. Short communication. Fish mouth dimensions and size selectivity in a Portuguese long-line fishery. *Journal of Applied Ichthyology* 13:41-44.
- Kenchington, T. J. 1993. Estimation of the functional form of selectivity by baited hooks: a graphical approach. *Canadian Journal of Fisheries and Aquatic Sciences* 50:772-780.
- Krebs, C. J. 1989. *Ecological methodology*. New York, Harper Collins, 654p.
- Lokkeborg, S. and A. Bjordal. 1992. Species and size selectivity in longline fishing: a review. *Fisheries Research* 13:311-322.
- McCracken, F. D. 1963. Selection by cod-end and hooks on cod, haddock, flatfish and redfish. *ICNAF Special Publication* 5:131-155.
- Millar, R. B. 1995. The functional form of hook and gillnet selection curves cannot be determined from comparative catch data alone. *Canadian Journal of Fisheries and Aquatic Sciences* 52:883-891.
- Morais, P. J. 1990. Selectividade do anzol relativamente ao *Pagellus bogaravero* (Goraz) e ao *Helicolenus dactylopterus dactylopterus* (Boca negra), pescados nos Açores. Faro, Universidade do Algarve, 74p.
- Otway, N. M. and J. R. Craig. 1993. Effects of hook size on the catches of undersized snapper *Pagrus auratus*. *Marine Ecology Progress Series* 93:9-15.
- Pope, J. A., A. R. Margetts, J. M. Hamley, and E. F. Akyuz. 1975. Manual of methods for fish stock assessment. Part III - Selectivity of fishing gear. *FAO Fisheries Technical Paper* 41:1-65.
- Preen, A. R. 1996. Infaunal mining: A novel foraging method of loggerhead turtles. *Journal of Herpetology* 30:94-96.
- Ralston, S. 1982. Influence of hook size in the Hawaiian deep-sea handline fishery. *Canadian Journal of Fisheries and Aquatic Sciences* 39:1297-1302.
- Scheiner, M. S. and J. Gurevitch, Eds. 1993. *Design and analysis of ecological experiments*. London, Chapman & Hall, 445p.
- Sousa, F. 1996. Estudo da eficiência relativa e selectividade do palangre fundeado na pesca demersal Açoreana. Unidade de Ciências e Tecnologias dos Recursos Aquáticos. Faro, Universidade do Algarve, 72p.

Sousa, F., E. Isidro, and K. Erzini. In press. Semi-pelagic longline selectivity for two demersal species from the Azores: the black spot sea bream (*Pagellus bogaraveo*) and the rockfish (*Helicolenus dactylopterus dactylopterus*). Fisheries Research.

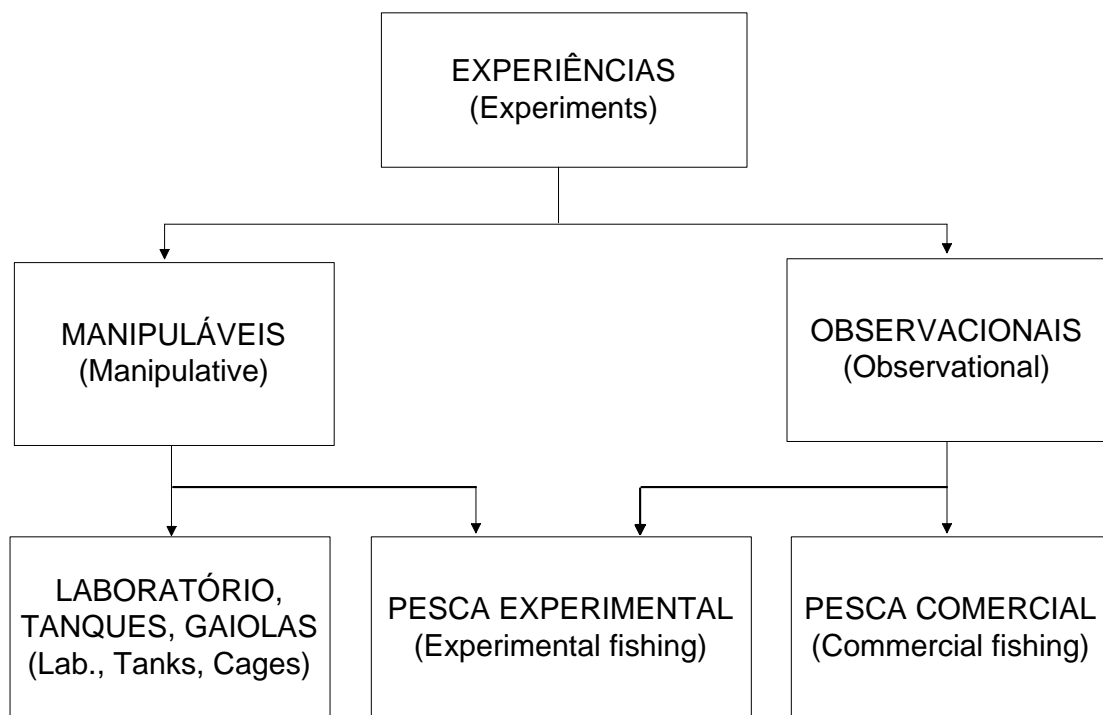


Figura 1 - Tipos de experiências.

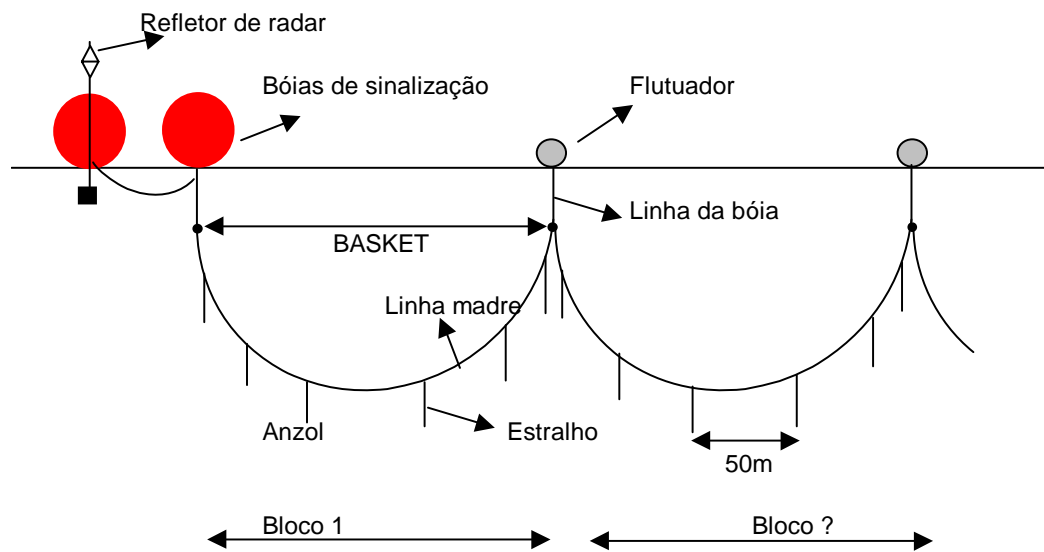


Figura 2 - Esquema geral de um palangre de meia água, a ser completado através da discussão.

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

ETAPAS	VARIÁVEIS
ATRACÇÃO: (Attraction)	<u>Isco, profundidade</u> , 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)	<u>Tamanho e forma do anzol</u> 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)	<u>Tamanho e forma do anzol, tipo de estralho</u> 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. mackerel
3. depth of buoy line: 3 fathoms vs. 6 fathoms.

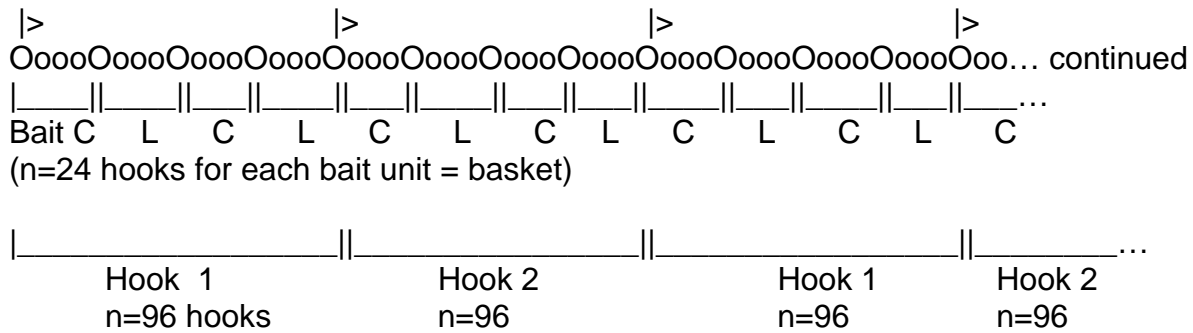
Workshop participants identified other variables (e.g., light sticks), but there was consensus that the three variables chosen were the most important. The experiment will be conducted during the 4 primary months of the swordfish fishery in the Azores (June, July, October, and November). A commercial 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 facilitate 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.



- > = 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

- Balazs, G.H. and S.G. Pooley. 1994. Research plan to assess marine turtle hooking mortality: results of an expert workshop held in Honolulu, Hawaii, November 16-18, 1993. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-201. 166 pages.
- Bolten, A.B., K.A. Bjorndal, H.R. Martins, T. Dellinger, M.J. Biscoito, S.E. Encalada and B.W. Bowen. 1998. Transatlantic developmental migrations of loggerhead sea turtles demonstrated by mtDNA sequence analysis. *Ecological Applications* 8:1-7.
- Bolten, A.B., K.A. Bjorndal and H.R. Martins. 1994. Life history model for the loggerhead sea turtle (*Caretta caretta*) population in the Atlantic: Potential impacts of a longline fishery. Pages 48-54 in G.H. Balazs and S.G. Pooley (eds.), *Research Plan to Assess Marine Turtle Hooking Mortality: Results of an Expert Workshop Held in Honolulu, Hawaii, November 16-18, 1993*. NOAA Technical Memorandum NMFS-SWFSC-201.
- Bolten, A.B., J.A. Wetherall, G.H. Balazs, and S.G. Pooley (compilers). 1996. Status of marine turtles in the Pacific Ocean relevant to incidental take in the Hawaii-based pelagic longline fishery. NOAA Technical Memorandum. NOAA-TM-NMFS-SWFSC-230. 167 pages.
- Williams, P., P.J. Anninos, P.T. Plotkin, and K.L. Salvini (compilers). 1996. Pelagic longline fishery-sea turtle interactions: Proceedings of an industry, academic and government experts, and stakeholders workshop held in Silver Spring, Maryland, 24-25 May 1994. NOAA Technical Memorandum. NMFS-OPR-7. 77 pages.
- Witzell, W.N. and J. Cramer. 1995. Estimates of sea turtle by-catch by the U.S. pelagic longline fleet in the western north Atlantic Ocean. NOAA Technical Memorandum NMFS-SEFSC-359. 14 pages.
-

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:

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

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:

$$\mu = \mu_{11} + \delta_A + 1/2 \delta_B.$$

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:

$$\begin{array}{ll} {}_A H_0: \mu_{i.} = \mu & \text{for all } i \\ \text{and } {}_B H_0: \mu_{.j} = \mu & \text{for all } j \end{array}$$

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:

$$\begin{aligned}
{}_A H_A: \quad & \mu_1 = \mu - \delta_A \\
& \mu_2 = \mu \\
& \mu_3 = \mu + \delta_A
\end{aligned}$$

$$\text{and } {}_B H_A: \quad \begin{aligned}
& \mu_{.1} = \mu - \frac{1}{2} \delta_B \\
& \mu_{.2} = \mu + \frac{1}{2} \delta_B
\end{aligned}$$

These are equivalent to:

$$\begin{aligned}
{}_A H_A: \quad & \mu_2 = \mu_1 + \delta_A \\
& \mu_3 = \mu_1 + 2 \delta_A
\end{aligned}$$

$$\text{and } {}_B H_A: \quad \mu_{.2} = \mu_{.1} + \delta_B$$

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 μ_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 μ_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 μ_2 , and γ , with μ_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 μ_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

${}_A H_0$ and ${}_B H_0$ 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 $1 - \beta$) 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 ${}_A H_0$ cannot be achieved under the design constraints assumed (Table 1). Tests of ${}_B H_0$ are even less powerful than those for ${}_A H_0$, 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 ${}_A H_0$. Tests of ${}_B H_0$ 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 $\alpha = 0.10$), 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, μ_2). Assumes $\alpha = 0.05$ and $\omega = 1.01$.

μ_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

Table 2. Approximate power of F test for detecting proportional differences in the mean take rate of turtles (γ) between 2 bait types given assumed current mean take rate (turtles per 1,000 hooks, μ_2). Assumes $\alpha = 0.05$ and $\omega = 1.01$.

μ_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	<0.30	<0.30	0.31
0.5	<0.30	<0.30	<0.30	0.30	0.35	0.47	0.56
1.0	<0.30	<0.30	0.31	0.42	0.60	0.76	0.84
2.0	<0.30	0.30	0.47	0.72	0.88	0.97	0.99

Closing Remarks

Helen R. Martins

According to our first agenda our Director, Ricardo Santos, was to have closed this workshop. However, as he had to be away on other duties, the task was left to me.

First of all, I would like to thank profoundly our colleague Alan Bolten for the initiative, enthusiasm and patience he has shown in order to bring the workshop to a successful conclusion, and also Jerry Wetherall of the National Marine Fisheries Service who came a long way from Hawaii to support us. We are very grateful to the fishermen who sacrificed their time to help us with their expertise.

A special thank you to my colleagues at DOP who presented information that made us better understand our objective.

Many thanks to all of you!

Comentários de encerramento

Segundo a primeira tínhamos o nosso Director Ricardo Santos a fazer o encerram, ento do workshop. Porém, ele teve outros compromissos e a tarefa passou para mim.

Antes de mais, quero agradecer profundamente ao nosso colega Alan Bolten pela sua iniciativa, entusiasmo e paciência com o fim a levar a cabo com sucesso este projecto e ao Jerry Wetherall do National Marine Fisheries Service do E.U.A. que fez a longa viagem do Hawaii para nos apoiar e aos pescadores que fizeram o sacrifício de nos dar algum do seu precioso tempo para nos ajudar. Também agradeço aos meus colegas no DOP que apresentaram comunicações para nos ajudar a perceber melhor o nosso objectivo.

Para todos, muito obrigada!