AERIAL SURVEY APPLICATIONS FOR ASSESSING BLUEFIN TUNA ABUNDANCE, DISTRIBUTION, AND AGE STRUCTURE IN THE NORTHWEST ATLANTIC : A PILOT STUDY

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SUMMARY

A pilot study was conducted in September, 1994, to examine the feasibility of applying aerial line transect methods to the problem of estimating bluefin tuna abundance in New England waters. This approach, unlike using data collected on-board spotter pilot aircraft, relies upon a sampling design in which search effort is distributed in a representative fashion with respect to the distribution of fish within the study area. Statistically-based methods have been developed which can result in precise estimates of abundance, provided sufficient information can be collected. Application of a vertical imaging system was also evaluated for the purpose of obtaining size measures of the fish observed during the survey.

RESUMÉ

Une étude pilote a été menée au mois de septembre 1994 pour examiner la possibilité d'appliquer les méthodes de prospection aérienne par sections transversales pour résoudre le problème de l'estimation de l'abondance en thon rouge dans les eaux de Nouvelle-Angleterre. Cette approche, contrairement à l'utilisation de données recueillies à bord d'avions de détection, se base sur un type d'échantillonnage selon lequel la recherche est distribuée de façon représentative par rapport à la distribution des poissons dans la zone étudiée. On a élaboré des méthodes basées sur la statistique, susceptibles de donner des estimations précises de l'abondance, en comptant obtenir suffisamment d'informations. Par ailleurs, on a évalué l'application d'un système d'image verticale pour mesurer les poissons observés lors de la prospection.

RESUMEN

En septiembre de 1994 se llevó a cabo un estudio aéreo para estudiar la posibilidad de aplicar métodos de transectos aéreos en la solución del problema de estimar la abundancia del atún rojo en aguas de New England. Este enfoque, al contrario del empleo de datos recogidos a bordo de aviones de detección, se basa en un tipo de muestreo en el cual la búsqueda se distribuye de forma representativa en relación con la distribución de los peces dentro de la zona estudiada. Se han desarrollado métodos basados en la estadística que podrán rendir estimaciones precisas de la abundancia, contando con que se pueda obtener la suficiente información. Igualmente se evaluó la aplicación de un sistema de imagen vertical, para medir los peces observados en el curso de la prospección.

Introduction

From August 30 through September 17, 1994, a pilot study was conducted to investigate the feasibility of utilizing aircraft to study bluefin tuna (*Thunnus thynnus*). Two primary questions were addressed:

1. Can line transect methodology currently utilized by the National Marine Fisheries Service (NMFS) to assess the distribution and abundance of marine mammals and sea turtles be used for bluefin tuna?

2. Will large-format, motion-compensated cameras, provide accurate data on school size and age structure of bluefin tuna schools that appear on or near the surface?

Bluefin tuna concentrate in waters from Cape Cod, Massachusetts, north into Canadian waters from late spring until early winter (J. Mayhew, pers. comm). A study area extending from just north of Portland, Maine to just south of Chatam, Massachusetts was chosen based on information provided by local bluefin tuna spotters (Figure 1).

Methods

The survey platform used was a NOAA owned, DeHavilland DHC-6 Twin Otter aircraft, modified with two plexiglass bubbles that provide trackline visibility and is equipped with a belly-camera port for vertical photography. This aircraft has been used extensively by NMFS for marine mammal, sea turtle, and marine debris surveys. These surveys were conducted at an altitude of 750 feet (229 meters) and a true airspeed of 100 knots (185 km/h). Two observers, one seated at each side-viewing bubble window, searched for bluefin tuna. A third observer recorded data on a laptop computer. Observers rotated positions approximately every thirty minutes to prevent fatigue. Headsets and an onboard intercom system provided communication between observers and the flight crew.

The aircraft is equipped with a Global Positioning System (GPS) interfaced with a laptop computer. A infrared thermometer mounted through an open port in the belly of the aircraft recorded sea surface temperature every 10 seconds. Perpendicular distances from the trackline to each sighting were measured by using calibrated interval marks, 10° apart on the plexiglass bubbles and also by the use of digital inclinometers equipped with red-dot sighting scopes. For all sightings the location, time, environmental parameters, and distance from trackline were recorded (see Appendix 1). All marine life sighted during the surveys were recorded into the tuna data base.

The aircraft was diverted from the trackline whenever schools of medium to giant bluefin tuna were sighted (see Table 1). These schools were circled in order to estimate the number of fish and to determine the specific size class. The number of fish were difficult to estimate whenever small, loosely aggregated schools were encountered. For these schools, individual splashes provided the only estimate of the number of bluefin present. Larger fish were more obvious for estimates, but also presented a problem when actively feeding over a large area.

Photogrammetry passes were attempted on all schools that remained near the surface and were comprised of medium to giant tuna. Fish spotters working in the area notified the survey aircraft of any concentrations of bluefin schools that appeared suitable for photogrammetry. On occasion, the line transect surveys were interrupted for photogrammetry, provided weather and sea state conditions were acceptable (i.e., low sea state and good sunlight penetration) and the transit to the area within reason.

Given a sufficient sample size, surface bluefin tuna density could be estimated as follows (Buckland et al. 1993):

$$\hat{D}=\frac{n\hat{f}(0)\bar{S}}{2L}$$

where

n = the number of school sighted,
L = the transect length,
S = the average number of fish per school, and
f(0) = the probability density function evaluated at the trackline (see Buckland et al. 1993).

The probability of sighting a school should be highest on the trackline, where it is assumed to equal one and decrease monotonically with distance from the trackline.

Results

Forty-nine bluefin tuna schools, totaling 2047 fish were sighted during the pilot project (Table 1). Of these sightings, 32 were made while on-effort, during line transect surveys. Productive areas for bluefin tuna were often active with other marine life. Fin, humpback, and minke whales as well as basking sharks, seabirds, and ocean sunfish were frequently sighted in the same area (Table 2).

Frequencies of on-effort sightings in each distance interval were plotted from the trackline (Figure 2). There is a distinct spike in the sightings in the interval from 132-192 meters.

Photogrametry was attempted on six bluefin schools. Several large whales and dolphin herds, on or very near the transect line, were also photographed. The majority of bluefin tuna schools encountered did not remain at the surface for extended periods, creating quite a challenge for low pass photogrametry. Even during ideal sea conditions and optimal sunlight penetration, the fish did not always show. Time of year, as well as weather and tidal state, are probably critical in obtaining suitable photographs. Photogrametry results will be addressed in a separate report.

Discussion

The sightability of bluefin is closely related to sea conditions, cloud cover, and possibly tidal state. Ideally, surveys should be conducted when the sea state is Beaufort 0-2 and not conducted when seas exceed a Beaufort 2 (Appendix 2). Sunlight penetration was very important for sighted schools just under the surface that did not create a detectable surface disturbance. However, sunlight penetration was not as critical on days when the sea state remained Beaufort 0-1.

Too few bluefin tuna schools were sighted to be able to draw conclusions on the utility of line transect methods in estimating bluefin density. The probability of sighting a school should decrease with distance from the trackline. However, there was a distinct spike in the interval from 132-192m. Given that only 28 distances were recorded, this could easily be due to chance alone. With a larger sample (e.g., 100 schools) the detection curve may be monotonically decreasing and thus applicable to line transect theory. While sample sizes of about 30 may be more typical for any one given survey, sightings from several surveys could be pooled to form a generalized bluefin tuna school detection curve which could be applied to each survey.

If possible, future surveys should be conducted between late June and the end of August when survey conditions are optimal. Sighting cues for bluefin are not as obvious as cues for marine mammals or sea turtles. A larger survey window should be considered, rather than a 3:1 (3 days allocated for each flight day needed) ratio normally used for other aerial surveys, a window of 4:1 would increase the chances of success for bluefin tuna surveys. Finally, assembling a team of trained observers with experience in sighting fish schools should be a priority.

Recommendations

The following problems and questions need to be addressed before future surveys are planned:

1. Bluefin tuna are not randomly distributed. A survey design that would allow "Hot" areas within the study block to be sub-sampled should be considered. According to the local fish spotters these active areas may change from year to year, so preplanning may not be feasible. These active spots could be identified during the standard line transect survey and sub-sampled after each block is completed or as soon as the active areas are identified.

2. A study is needed to investigate the amount of time bluefin tuna spend on the surface and the time of day they are likely to appear.

3. Counts of the number of fish are only minimum estimates. Only the fish visible on the surface or the separate splashes were recorded. Counting the number of schools spotted and not the number of fish may be a better approach. For future surveys, aerial photographs may provide better estimates of school sizes.

4. Should splashes from feeding activity, but where fish are not visible be counted as a sighting?

5. Are bluefin the only tuna-like fish likely to be seen this time of year. Small bonito were being caught off the coast of Maine during the survey window. Observers would have a difficult time separating bonito and small bluefin tuna, especially if they are scattered and feeding.

6. Sighting functions for tuna surveys may not fit standard line transect theory. The detectability of certain cues may actually increase with the distance from the aircraft. With glare present, surface disturbances are often easier to detect beyond the trackline. Analytically this can be dealt with by left truncating the sighting function.

7. The variance between a "show day" when bluefin spend much of their time on the surface, and a normal survey day could be large. Can this be addressed analytically?

8. If possible, I recommend consolidating surveys of marine mammals, sea turtles, marine debris, and bluefin. Cooperative surveys could easily be designed. Additionally, this would help reduce the cost to all users and make optimal use of aircraft time .

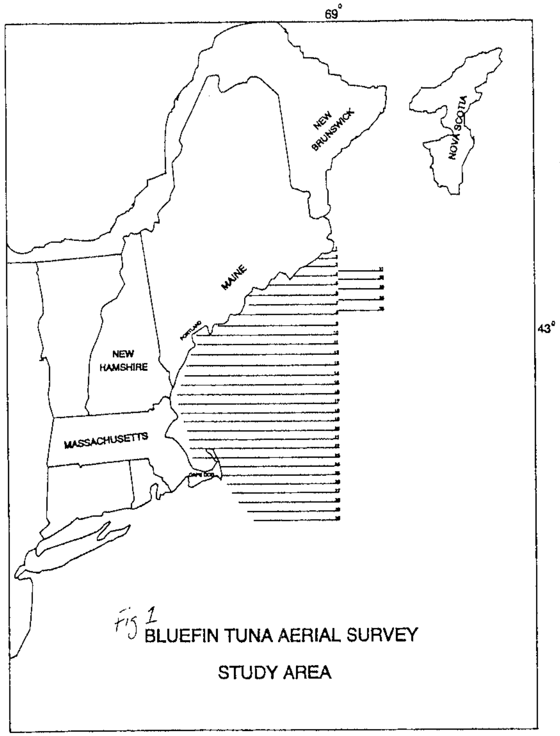

Fig 1 BLUEFIN TUNA AERIAL SURVEY STUDY AREA

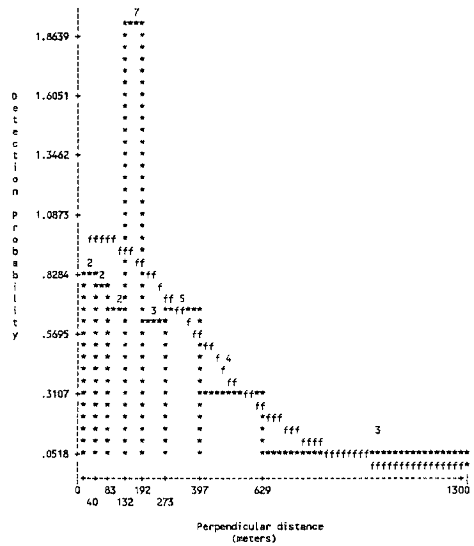

Figure 2. Bluefin tuna school detection curve.

Table 1. **MARINE MAMMAL and FISH SIGHTINGS**

Fish	**Sightings**	**Number of Fish or Schools**
Bluefin Tuna	49	2047 fish
Mackeral	3	5 schools
Ocean Sunfish	69	73 fish
Basking Sharks	38	49 fish
Bluefish	5	14 schools
Blue or Unid. sharks	54	68 fish
Shark schools	1	1 schools
Unidentified Small Fish schools	7	7 schools

Marine mammals	**Sightings**	**Animals**
Fin Whales *Balaenoptera physalus*	41	60
Humpback *Megaptera novaeangliae*	46	74
Unidentified Large Whales	16	26
Pilot Whales *Globicephala spp.*	10	66
Minke Whales *Balaenoptera acutorostrata*	9	9
Unidentified Small Whales	4	8
Bottlenose Dolphins *Tursiops truncatus*	2	8
White-sided Dolphin *Lagenorhynchus acutus*	35	2637
Harbor Porpoise *Phocoena phocoena*	39	190
Unidentified Dolphins	13	954
Harbor Seals *Phoca vitulina*	10	19
Unidentified Seals	7	11