Aerial Surveys of Texas Commercial Fishing Vessels[1]

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Abstract: Low altitude aerial surveys were conducted at approximately monthly intervals from 1 April 1987 to 31 March 1988 to determine temporal and geographic distribution of commercial fishing in Texas bay and Gulf (Texas Territorial Sea) areas. Observers counted a total of 4,841 bay commercial vessels and 1,906 Gulf commercial vessels conducting 7 types of fishing activities over the 12-month study period. Commercial shrimping made up 87.7% of all commercial activity. Most activity was observed between May and November. Thirty-nine percent of the bay commercial activity was concentrated in Galveston Bay while 27% was in Matagorda Bay. San Antonio, Aransas, and Corpus Christi bay systems collectively yielded 29% of the commercial bay vessel counts. Gulf commercial shrimping was evenly distributed along the entire coast with a slightly higher concentration around the Galveston offshore area. Photography and ground counts were assessed as verification to observer counts. Airborne observation of commercial fishing pressure and distribution proved to be a good method for assessing the commercial fishery. Slides provided best resolution for counting but not activity determination. Ground verification was statistically valid. Aerial costs per hour were approximately $160.00 and flights averaged 10.8 hours per month.

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Monitoring Texas' commercial fishing activity in bays and the Texas Territorial Sea (TTS) is an important aspect of managing the state's coastal fisheries. In order to accurately assess temporal and geographical distributions of fishing effort, data obtained through direct observations are preferred to reduce bias.

Numerous methods of aerial reconnaissance have been used to monitor human fishing activities. Marine sport fishing effort (using fishing pole counts) was monitored by air and used to determine pressure by Pinkas et al. (1968). Pressure estimates were compared to ground roves accomplished in conjunction with the aerial flights.

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Frisbee and Ritchie (1963) used aerial surveys to count recreational fishing pressure in the lower Potomac estuary. Aerial surveys were used to determine spatial distribution of lobster fishing effort in the southern Gulf of St. Lawrence (Conan and Maynard 1983) and Pringle et al. (1986) evaluated costs associated with aerial surveys of Canadian lobster fishing effort. The Texas Parks and Wildlife Department (TPWD) has successfully used line transect aerial surveys to estimate the number and temporal distribution of crab traps in Texas bays (Hammerschmidt and Benefield 1986).

In addition to aerial observer surveys, photography has been widely adapted (Norton-Griffiths 1973, 1974; Sinclair 1972, 1973; Conan and Maynard 1983) as a survey technique to help overcome problems with observer performance. Aerial photographs were used by Scott et al. (1985) for comparison of observer counts and estimation of individual and school sizes of Pacific cetaceans.

The objective of this study was to document seasonal and geographic distributions of commercial fishing activities in Texas bay and Gulf areas using an aerial observer program developed by the Texas Parks and Wildlife Department. Aerial photography and simultaneous ground counts were used to verify accuracy of aerial counts.

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Methods

Study Area

The Texas coast was divided into 2 areas for the purpose of aerial coverage. Area 1 was the upper coastal bay systems from Sabine Lake to Matagorda Bay and adjacent Gulf area, and Area 2 was the lower coast bay systems from San Antonio Bay to lower Laguna Madre and adjacent Gulf area. In order to randomize survey times among major areas, bay and Gulf areas were further subdivided into sectors of approximately equal flight times (2.5 to 3 hours). Counts were grouped by major bay system and major Gulf zone.

Aerial Survey

Monthly surveys were conducted from 1 April 1987 to 31 March 1988 along the Texas coast. Two single engine aircraft, a Cessna 182 and a Cessna 210, were used for almost all flights. A Cessna 310 was used on an emergency basis on 2 flights. Two days were required to cover the 1.58 million ha (Diener 1975) of Texas coastal area using single engine aircraft. However, because it was possible to census all bay and Gulf areas, it was unnecessary to extrapolate fishing effort estimates from line transect data.

Primary and secondary survey starting days and upper and lower coast starting

order were derived with computer generated random numbers. Surveys took place either on the same or contiguous days depending on weather and aircraft schedules. Several survey days were assigned (not randomly generated) because they were of special interest to the TPWD. These were 15 May (bay shrimping season opening), 15 July (bay shrimping closure), 15 August (bay shrimping season reopening), and 1 November (oyster season opening).

Flights were accomplished generally between 0830 to 1130 and 1330 to 1630 due to visibility and sun angle considerations. An 1130–1330 break was used to reduce observer fatigue. Approximately half the total flight period was accomplished during the morning and half in the afternoon with routes randomly assigned.

During surveys, ground speed was between 80–100 knots in the bays and 120–140 knots in the Gulf. Altitude in the bay areas was usually 122–243 m and 762–1,219 m in Gulf areas. If needed, second fly-overs were used to aid in determining counts of densely clustered vessels or activity of vessels within densely clustered groups. Airborne observers, 1 on each side of the aircraft, recorded their tallies and locations on data forms (TPWD Roving Count Data sheets) and bay system maps, respectively. Observers documented vessel activity, vessel fishing status (underway, stationary, or actively fishing), and time of encounter. Geographical location was determined with shoreline landmarks and LORAN coordinates. The same observers were used for both morning and afternoon flights; however, different observers were generally used for upper and lower coast counts.

Commercial fishing vessels were identified by the gear visible on board and their activity. Vessel design, trawls, outriggers, bait boxes, traps, longline buoys and other equipment associated with commercial fishing were generally visible by air and aided in distinguishing these vessels from other commercial vessels (e.g. crewboats and recreational fishing vessels). Vessels traveling within an area were considered "in the fishery" and were given an activity of "underway" to distinguish them from vessels that were actually in the process of fishing. Because the survey was considered a "snapshot" of the fishery at a given moment, traveling vessels were placed in the location they were encountered.

Ground Surveys

Ground surveys were conducted in coordination with bay area aerial surveys. Ground surveys were carried out on the water by boat in an area that could be covered in approximately 1 hour. Single fly overs above these areas were made as close to the midpoint of the ground survey time as possible. The 1-hour time enabled ground observers to cover sufficient area without allowing appreciable ingress or egress of fishing vessels. Ground survey areas were randomly assigned by month to 1 of the 4 major bay systems within the supper and lower coast bay areas. Ground observers documented number of vessels, fishing activity, and time of encounter.

Aerial Photography

Aerial photographs were taken with a hand-held Canon 35mm SLR camera with 50mm and 150mm lenses to verify counts of densely clustered vessels and to

determine feasibility of aerial photographic methods. Both print (ASA 200) and slide (ASA 200 Ektachrome) film were used to determine applicability of photographs. Observer counts and photographic counts were compared with a paired *t*-test to determine relative accuracy of aerial observers.

Results

Between 1 April 1987 and 31 March 1988, 6,746 commercial fishing vessels (72% in bays, 28% in TTS) were counted during 12 trips. The majority of fishing vessels in all areas were engaged in shrimping activities, with substantially less participation in other fisheries (Table 1).

Temporal Distribution

Peak commercial activity in bays was recorded from June to November, during which time 88% of all bay fishing vessels were observed (Table 2). About 86% of these vessels were shrimping, with peak vessel activity during August (741). Less than 5% of the coastwide shrimping activity was recorded each month during April (bait shrimping only season), May (bay shrimping season), and December (bay shrimping season). Peak months for Gulf shrimp vessel counts were August, September, and November, averaging 300 vessels per month (Table 2). Gulf shrimp vessel counts were lowest during the winter months of January through March. Low vessel counts during June were due to closed season in the 4- to 7-fathom zone (Fig. 1). Almost 70% of the Gulf shrimp vessels were counted during the period from July through December.

Commercial oystering was the second most common bay fishing activity (N = 623), with highest counts recorded in December (164), February (103), and March (143). Because the oyster season was closed in November, vessels encountered during this month were most likely harvesting from private leases. May through October is closed to oyster harvest on public reefs (Fig. 1). However, transplanting and harvesting from private leases occurs in Galveston Bay during this period, as well as during the public reef harvest season which accounts for oyster vessel sightings during these months. Lease activity during May–October accounted for about 16% of the total annual oyster vessel count.

Table 1. Total vessels observed during 12 aerial surveys in Texas bay and Gulf waters from 1 April 1987 to 31 March 1988.

	Bay		Gulf	
Activity	Total	%	Total	%
Shrimping	3,866	79.9	1,881	98.7
Finfishing	20	0.4	24	1.3
Crabbing	332	6.8	0	0.0
Oystering	623	12.9	0	0.0
Total	4,841	100.0	1,905	100.0

Table 2. Monthly counts of commercial fishing vessels in Texas bay and Texas Territorial Sea (TTS) by observed activity 1 April 1987 to 31 March 1988.[a]

Month	Bay					Gulf			Combined Total
	Shrimp	Finfish	Crab	Oyster	Total	Shrimp	Finfish	Total	
Apr 1987	140	0	12	65	217	147	0	147	364
May	143	0	13	16	172	154	0	154	326
Jun	558	0	13	26	597	33	0	33	630
Jul	423	0	31	23	477	180	9	189	666
Aug	741	1	35	2	779	309	14	323	1,102
Sep	620	1	105	8	734	291	0	291	1,025
Oct	514	0	7	8	529	116	1	117	646
Nov	535	0	11	15	561	300	0	300	861
Dec	125	2	48	164	339	204	0	204	543
Jan 1988	15	3	0	50	68	50	0	50	118
Feb	15	9	45	103	172	51	0	51	223
Mar	37	4	12	143	196	46	0	46	242
Total	3,866	20	332	623	4,841	1,881	24	1,905	6,746

[a]No directed commercial fishing for blue crab or oyster takes place in Gulf.

Commercial blue crab vessels ranked third (332) in total bay vessel number. Peak months for crab vessel counts were July through September, and December and February. Unlike oysters and shrimp there is no closed season for blue crabs (Fig. 1). Bay finfishing vessels were encountered mainly during the period from December through March with a peak of 9 observed in February.

Slightly more vessels were counted in the morning survey (3,798) than in the afternoon survey (2,948). Bay fishing vessels were more numerous in the morning period (2,808) than in the afternoon (2,033), while Gulf vessel counts were only slightly different between early and late periods (990 versus 915 for early and late periods, respectively).

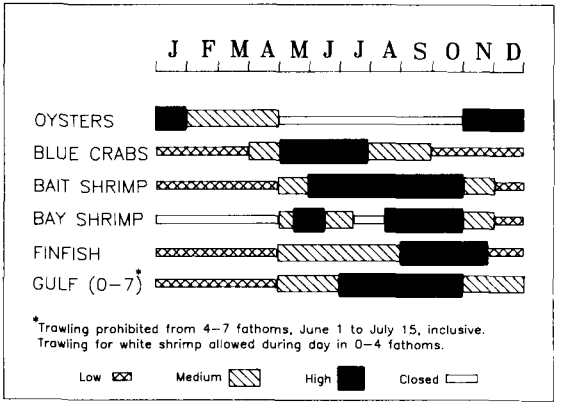

Figure 1. Seasonal landings by commercial fisheries in Texas (Quast et al. 1988).

Geographic Distribution

Of the 4,841 bay vessels observed during surveys, 39.3% were recorded in Galveston Bay, 27.3% in Matagorda Bay, 12.3% in San Antonio Bay, 8.6% in Aransas Bay, and 8.4% in Corpus Christi Bay (Table 3). Commercial shrimping was the major fishing activity in all bay systems (averaging 79.8%) except Sabine Lake in which blue crab fishing (51.2%) was of greater importance than shrimping (46.3%).

Gulf commercial fishing counts were grouped into standard Gulf statistical zones used by TPWD (Osburn et al. 1987). Highest vessel counts were recorded in Area 17 (511) whereas lowest counts were found in Area 20 (282) (Table 3). Few commercial fishing boats other than shrimp boats were seen in any Gulf area.

Survey Costs

Aerial survey costs averaged approximately $160.00 per hour and included $120.50 per hour for the aircraft and pilot and $38.50 per hour for 2 Coastal Fisheries staff (observers) and vehicles. Average flight time per month was 10.8 hours. Average monthly observer time was calculated at 13 hours and included travel time to and from the airport. The approximate total cost for 12 monthly surveys of the Texas coast was $21,600.00.

Table 3. Geographic distribution of commercial fishing vessels observed in Texas bays and Texas Territorial Seas (TTS) during monthly aerial surveys, 1 April 1987 to 31 March 1988.

Area	Vessels Per Activity				Total
	Shrimp	Crab	Finfish	Oyster	
Bay Area					
Sabine Lake	21	19	0	1	41
Galveston Bay	1,468	45	0	391	1,904
Matagorda Bay	1,201	39	0	84	1,324
East Matagorda Bay	55	8	0	6	69
San Antonio Bay	373	168	0	53	594
Aransas Bay	301	29	0	88	418
Corpus Christi Bay	383	12	10	0	405
Upper Laguna Madre Bay	51	7	10	0	68
Lower Laguna Madre Bay	13	5	0	0	18
Total Bay	3,866	332	20	623	4,841
Gulf Area (TTS)					
TTS Area 17	373	0	2	0	375
TTS Area 18	497	0	14	0	511
TTS Area 19	333	0	8	0	341
TTS Area 20	282	0	0	0	282
TTS Area 21	396	9	0	0	396
Total TTS	1,881	0	24	0	1,906
Total bay and TTS	5,747	332	44	623	6,746

Ground Surveys

A paired *t*-test (SAS Institute Inc. 1982) was conducted on the mean difference of ground versus aerial count data. Overall, 238 vessels were observed in ground surveys, whereas aerial counts over the same areas reported 226 observed vessels. Average deviation was <1 vessel/month; count deviations ranged from 0 to 9. No significant difference was found between ground and aerial counts (t value = 1.15; $P > |T| = 0.2618$, 22 d.f.).

Aerial Photography

Slide film provided the best resolution of fishing vessels because the images could be projected onto a screen. Comparison of 72 counts between photographs and observers was not statistically differentiated due to a lack of resolution (i.e. inability to identify area of coverage), difference in area covered by photographs, and inability to interpret activity. Skiffs (crabbing and finfishing) showed poor resolution on slide film unless singled out and photographed at close range. Print film resulted in poor resolution photographs and made counting difficult.

Discussion

Aerial surveys are a feasible method for collecting coastwide data on commercial fishing pressure in a short period of time. Aerial surveys of commercial vessels are cost effective, and a complete census of Texas' marine waters can be accomplished in a 2-day period, providing a "snapshot" of vessel activity and location. The technique developed (Conan and Maynard 1983, Norton-Griffiths 1973, Hammerschmidt and Benefield 1986) to assess different targets differ markedly in the following characteristics: procedural implementation and technical sophistication, manpower and monetary costs, final data format, quality of estimates. This was the initial year of data collection in a program which is designed to assess commercial fishing pressure. Nevertheless, the data are sufficient to give an approximation of both the cost effectiveness and potential uses of the technique. Cost of aerial flights were approximately \$8.77/km^2, while Pringle et al. (1986) estimated a cost of approximately \$9.45/km^2. Cost differences are most likely due to economies of scale because Pringle et al. (1986) only covered 3,001 km^2 compared to the 189,000 km^2 covered in our study. Limitations to conducting aerial surveys include weather, day length, and the limited number of surveys that can be conducted coastwide in a given period.

Comparison of ground surveys and aerial surveys in the bays indicated that results from the 2 methodologies were analogous. Frisbie and Ritchie (1963) found that pressure estimates from ground counts were slightly lower than aerial roves. They attributed this increase to "fair weather flying" which biased the number of fishermen on the water during flights. Ground surveys could be used to obtain more specific information on individual vessels in a given area, if required. However, ground surveys were difficult to coordinate with aerial surveys and were restricted in the amount of area that could be adequately covered. Differences between aerial

counts and ground counts were probably due to the migration of boats into and out of the study area during the ground count period. Ground surveys were not accomplished in the Gulf because of manpower and monetary constraints. No attempt was made to compare counts of Gulf vessels by the 2 methodologies, however, because speed and altitude changed ground surveys of Gulf aerial surveys would be necessary to compare them.

Aerial photography of commercial fishing vessels using a hand-held 35mm camera was not an adequate method for verifying count data because resolution was sacrificed to obtain cluster photographs and areas of coverage were not easily delineated. Pringle et al. (1986) determined that aerial color photography was 10.5 times the cost of direct visual scanning. They concluded that aerial color photography would reduce the chance of human error and indicated that either aerial color photography or aerial visual sensing provided excellent instantaneous assessments of overall patterns of lobster fishing effort distribution.

In order to determine the exact fishing activity, in many cases, it was necessary to observe the motion of the vessel (crab skiffs and oyster vessels making their characteristic circular motion) or observation of an oil sheen from freshly baited crab pots or commercial trot lines in the case of finfish fishermen. Motionless pictures in many cases gave little indication as to motion of vessel or could not detect subtle details like oil sheens left by freshly baited traps. In any case, slide film proved better than print film for photograph presentation and interpretation; however, neither had the resolution required for consistent data verification. Video photography could alleviate the problem of motionless film and may be a viable alternative to slide or print film. Slower film (25 ASA) may reduce the graininess of photographs but would not address the problem of lack of motion. Use of equipment designed for aerial photography (e.g. Hasselblad or video camera) and slower film speeds may enhance our ability to use aerial photography to determine commercial fishing activity.

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