Literature Cited

COX, B. A., AND R. G. MAUERMAN.
1976. Incidental catch and disposition by the Brownsville-Port Isabel Gulf shrimp fleet. Cameron Co. Ext. Ser., San Benito, TX, and Texas Shrimp Assoc., Brownsville TX, 55 p.

FRITTS, T. H., A. B. IRVINE, R. D. JENNINGS, L. A. COLLUM, W. HOFFMAN, AND M. A. MCGEHEE.
1983. Turtles, birds and mammals in the northern Gulf of Mexico and nearby Atlantic waters. U.S. Fish Wildl. Serv. Div. Biol. Ser., Wash., D.C., 455 p.

HILLESTAD, H. O., J. I. RICHARDSON, AND G. K. WILLIAMSON.
1978. Incidental capture of sea turtles by shrimp trawlermen in Georgia. Proc. Ann. Conf. Southeast. Assoc. Fish Wildl. Agencies, p. 167-178.

HOPKINS, S., AND J. RICHARDSON.
1984. A recovery plan for marine turtles. U.S. Gov. Print. Off., 281 p.

RABALAIS, S. C., AND N. N. RABALAIS.
1980. The occurrence of sea turtles on the south Texas coast. Contrib. Mar. Sci. 23:123-129.

SNEDECOR, G. W., AND W. G. COCHRAN.
1967. Stastical methods. [6th ed.] Iowa State Univ. Press, Ames, IA, p. 536-537.

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THE RELATIONSHIP BETWEEN LUNAR PHASE AND GULF BUTTERFISH, *PEPRILUS BURTI*, CATCH RATE

Through the joint efforts of Japan and the United States, a research program was conducted in fall 1984 and spring 1985 to identify squid resources in the northern Gulf of Mexico (Grace 1984, 1985). Although large concentrations of squid were not located, commercial quantities of gulf butterfish, *Peprilus burti*, were encountered. Maximum sustainable yield (MSY) estimates from the spring data indicated annual potential catches of 50,000 t with a projected ex-vessel value of $19 million (Gledhill[1]). Although gulf butterfish are sufficiently abundant to support a fishery, critical gaps of information on gulf butterfish distribution and location exist which are needed in order to harvest this resource efficiently. Preliminary data from the U.S.-Japan joint surveys indicated that gulf butterfish catch rates were greatest at bottom temperatures of 15°-19°C. Subsequent scientific and commercial efforts at targeting gulf butterfish based upon bottom temperature have produced catches ranging from few individuals to many tons. In a recent study, we found that fishing success for gulf butterfish was often high for several days followed by periods of low success (Allen et al. 1986). This phenomena parallels catch patterns encountered by east coast gulf butterfish fishermen (Amos[2]), who suggest that lunar phase affects catch rates. We analyzed the effect of lunar phase on catch rates. The purpose of this paper is to present evidence that bottom trawling success for gulf butterfish is related to lunar phase.

Methods

Gulf butterfish catches from the two U.S.-Japanese joint surveys and from an additional gulf butterfish survey conducted by SEAMAP (August 1985) were examined. Initially, catch rates per hour of individual trawls were calculated per calendar day. A lunar day value (1-29) was assigned to each calendar day of trawling during the three cruises. Lunar day 1 was assigned to the third calendar day proceeding the new moon on through day 29 falling on the third calendar day following the last quarter moon phase. Mean catch (kg/hour per lunar day) was then calculated and plotted. Catches from trawled stations outside of the depth range in which gulf butterfish were caught during each trip (i.e., < minimum depth or > maximum depth) were not included when calculating mean catch/hour per lunar day.

The effects of moon phase and trip on natural log catch rates ($\ln(x + 1)$, where x = kg/hour per individual trawl) of gulf butterfish were investigated, using the general linear model (GLM) procedures (SAS) Institute (1982). Type III sums of squares were used for the analysis due to unequal number of observations in each subclass. Each observation from each trip was assigned into a lunar phase period (1-4). Mean catch ($\ln(x + 1)$/hour) and number of trawls sampled during each trip and lunar phase are presented in Table 1. An

[1]Gledhill, C. T. 1985. A preliminary estimate of gulf butterfish (*Peprilus burti*) MSY and economic yield. Unpubl. manuscr., 66 p. Southeast Fisheries Center, Mississippi Laboratories, National Marine Fisheries Service, NOAA, Pascagoula, MS 39568-1207.

[2]Duncan Amos, Georgia Marine Extension Program, P.O. Box Z, Brunswick, GA 31523, pers. commun. July 1986.

TABLE 1.—Mean catch (ln(x + 1)/hour) of gulf butterfish and number of trawls sampled during each trip and lunar phase.

Trip	Phase	Number	Mean catch
1	1	6	1.13
1	2	24	2.57
1	3	13	1.58
1	4	31	2.31
2	1	24	2.07
2	2	47	3.24
2	3	9	1.29
2	4	21	2.16
3	1	39	0.49
3	2	35	0.58
3	3	21	0.26
3	4	62	0.40

analysis of variance (ANOVA) model was developed to test for the effect of trip, lunar phase, and the interaction between trip and lunar phase. Scheffe's test was used to contrast each lunar phase with the other three phases.

Results

Peak catch rate was observed to occur in the first quarter moon phase following the new moon (Fig. 1). There was a highly significant difference among trips and lunar phases (Model 1, Table 2). The interaction between trip and lunar phase was not significant ($P = 0.33$) and was therefore dropped from the model resulting in Model 2 (Table 3). In model 2, there was a highly significant difference among trips and a significant difference among lunar phases. A comparison of means using Scheffe's test for each moon phase (Table 4) indicated that catch rate during the first quarter moon phase was significantly greater than catch rates during the last quarter, new, and full moon phases.

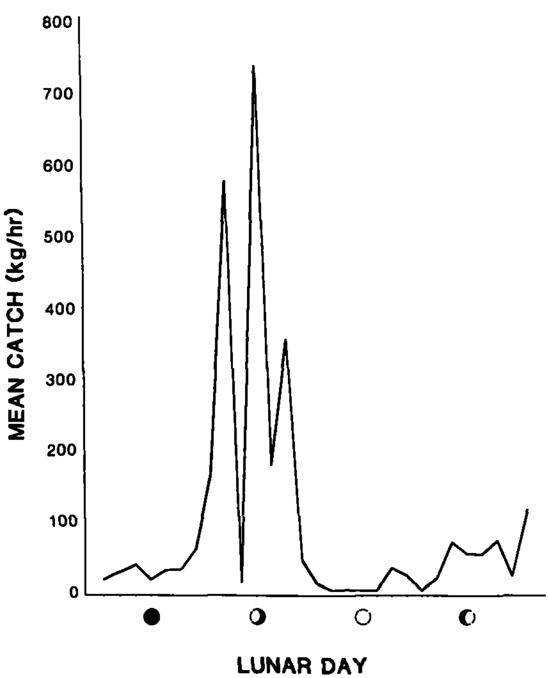

FIGURE 1.—Graph of mean catch (kg/hour) of gulf butterfish by lunar day.

TABLE 2.—Analysis of variance table testing the effects of moon phase (M), research trip (T), and the interaction between trip and moon phase (T * M) on gulf butterfish catch rates during three butterfish research surveys in the Gulf of Mexico 1984-85.

		MODEL 1		
Source	df	ss	*F*-ratio	Pr > *F*
Model	11	384.864	9.90	0.0001**
Error	320	1,130.662		
		TYPE III		
Variable	df	ss	*F*-ratio	Pr > *F*
T	2	175.758	24.87	0.0001**
M	3	43.110	4.07	0.0074**
T * M	6	24.353	1.15	0.3338

**Significant effect at $P < 0.01$.

TABLE 3.—Analysis of variance table testing the effects of moon phase (M) and research trip (T) on gulf butterfish catch rates during three butterfish research surveys in the Gulf of Mexico 1984-85.

		MODEL 2		
Source	df	ss	*F*-ratio	Pr > *F*
Model	5	360.511	20.35	0.0001**
Error	326	1,155.016		
		TYPE III		
Variable	df	ss	*F*-ratio	Pr > *F*
T	2	272.183	38.41	0.0001**
M	3	37.648	3.54	0.0149*

**Significant effect at $P < 0.01$.
*Significant effect at $P < 0.05$.

TABLE 4.—Mean catch rate per hour (ln(x + 1)/hour) by lunar phase

Lunar phase	Catch rate/hour
New Moon	1.09
First Quarter	2.21*
Full Moon	0.88
Last Quarter	1.24

*$P < 0.05$.

Discussion

Although lunar rhythmicity in marine organisms, particularly marine invertebrates, has long been recognized (Palmer 1974), lunar rhythms in which a single peak of activity occurs each month in fishes appear to be rare (Gibson 1978). Most accounts of variations in catch rate of commercially important species which correlate with moon phase refer to clupeids (Gibson 1978). Blaxter and Holliday (1963) suggested several possible explanations for the apparent lunar rhythmicity of clupeid catches including: 1) intensity of moonlight, 2) effect of tides, and 3) fishermen behavior.

Gulf butterfish are normally trawled during daylight when they concentrate near bottom following nocturnal vertical migration. However, this migration is difficult to describe because conventional echo sounding equipment poorly tracks gulf butterfish movement owing to atrophy of the swim bladder in gulf butterfish over 100 mm standard length (Horn 1970). Differences in catch rates between lunar phases may be attributed to changing vertical movements of gulf butterfish in the water column. The lunar pattern is probably not due to onshore-offshore movement out of the fishery's area of operation. In the three research cruises, sampling was stratified by bottom depth (36-585 m) and data do not suggest horizontal movements of gulf butterfish outside these depths.

In conclusion, further work on lunar rhythmicity relationships of gulf butterfish is needed. Results may greatly enhance commercial and scientific efforts in harvesting and surveying gulf butterfish, respectively, by identifying alternate fishing methods (e.g., midwater trawling) that successfully target gulf butterfish during all moon phases.

Literature Cited

ALLEN, R. L., J. H. RENDER, A. W. LIEBZEIT, AND G. W. BANE.
1986. Biology, ecology, and economics of butterfish and squid in the northern Gulf of Mexico. La. State Univ., Coastal Fish. Inst. Publ. 86-30, 169 p.

BLAXTER, J. H. S., AND F. G. T. HOLLIDAY.
1963. The behavior and physiology of herring and other clupeids. *In* F. S. Russell (editor), Advances in marine biology, Vol. 1, p. 262-393. Acad. Press, Lond.

GIBSON, R. N.
1978. Lunar and tidal rhythms in fish. *In* J. E. Thorpe (editor), Rhythmic activity of fishes, p. 201-213. Acad. Press, Lond.

GRACE, M.
1984. U.S.-Japan squid survey, 10/11-11/17/84, Nisshin Maru No. 201. U.S. Dep. Commer. Natl. Oceanic Atmos. Adm., Natl. Mar. Fish. Serv., Cruise Rep., 18 p.
1985. U.S.-Japan squid survey, 4/18-5/29/85, Nisshin Maru No. 201. U.S. Dep. Commer., Natl. Oceanic Atmos. Adm., Natl. Mar. Fish. Serv., Cruise Rep., 18 p.

HORN, M. H.
1970. Systematics and biology of the stromateid fishes of the Genus *Peprilus*. Bull. Mus. Comp. Zool. 140:164-271.

PALMER, J. D.
1974. Biological clocks in marine organisms. Wiley, Lond., 173 p.

SAS INSTITUTE, INC.
1982. SAS user's guide: Statistics. 1982 ed. SAS Institute, Cary NC, 584 p.

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MOVEMENTS OF COHO, *ONCORHYNCHUS KISUTCH*, AND CHINOOK, *O. TSHAWYTSCHA*, SALMON TAGGED AT SEA OFF OREGON, WASHINGTON, AND VANCOUVER ISLAND DURING THE SUMMERS 1982-85

Knowledge of the migration patterns of salmonids in the ocean is an important consideration in developing fishery management plans. Catches of coded-wire tagged salmon in the ocean have yielded much information on general distribution patterns of different stocks and species of salmon (see for example Hunter [1985], Garrison [1985], and Howell et al. [1985]). Other studies have dealt with movements of salmon tagged in offshore waters of the northern North Pacific Ocean (Hartt 1962, 1966; French et al. 1975; Godfrey 1965; Godfrey et al. 1975) and in coastal waters of British Columbia, Washinton, Oregon, and California (Milne 1957; Vernon et al. 1964; Kauffman 1951; Van Hyning 1951; Fry and Hughes 1951). Movements of juvenile salmon in coastal waters of the Gulf of Alaska were studied by Hartt and Dell (1986); in Georgia Strait, British Columbia, by Healey (1980); and in coastal waters off Oregon and Washington by Pearcy and Fisher (unpubl. manuscr.)[1].

[1]W. C. Pearcy and J. P. Fisher. Migration of coho salmon (*Oncorhynchus kisutch*) during their first summer in the oceans. Unpubl. manuscr. College of Oceanography Oregon State University, Corvallis, OR 97331.