COOK, A. F., N. E. STACEY, AND R. E. PETER.
1980. Periovulatory changes in serum cortisol levels in the goldfish, *Carassius auratus*. Gen. Comp. Endocrinol. 40:507-510.

HIROSE, K.
1976. Endocrine control of ovulation in medaka (*Oryzias latipes*) and ayu (*Plecoglossus altivelis*). J. Fish. Res. Board Can. 33:989-994.

JALABERT, B.
1976. In vitro oocyte maturation and ovulation in rainbow trout (*Salmo gairdneri*), northern pike (*Esox lucius*), and goldfish (*Carassius auratus*). J. Fish. Res. Board Can. 33:974-988.

KAYA, C. M., A. E. DIZON, AND S. D. HENDRIX.
1981. Induced spawning of a tuna, *Euthynnus affinis*. Fish. Bull., U.S. 79:185-187.

MATSUMOTO, W. M.
1966. Distribution and abundance of tuna larvae in the Pacific Ocean. *In* T. A. Manar (editor), Proceedings, Governor's Conference on Central Pacific Fishery Resources, p. 221-230. State of Hawaii.

MAZEAUD, M. M., F. MAZEAUD, AND E. M. DONALDSON.
1977. Primary and secondary effects of stress in fish: Some new data with a general review. Trans. Am. Fish. Soc. 106:201-212.

STRANGE, R. J., C. B. SCHRECK, AND J. T. GOLDEN.
1977. Corticoid stress responses to handling and temperature in salmonids. Trans. Am. Fish. Soc. 106:213-218.

SUNDARARAJ, B. I., AND S. V. GOSWAMI.
1977. Hormonal regulation of *in vivo* and *in vitro* oocyte maturation in the catfish, *Heteropneustes fossilis* (Bloch). Gen. Comp. Endocrinol. 32:17-28.

WITSCHI, E., AND C. Y. CHANG.
1959. Amphibian ovulation and spermiation. *In* A. Gorbman (editor), Comparative endocrinology, p. 149-160. Wiley, New York.

YOSHIDA, H. O.
1971. The early life history of skipjack tuna, *Katsuwonus pelamis*, in the Pacific Ocean. Fish. Bull., U.S. 69:545-554.

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ESTIMATING AND MONITORING INCIDENTAL DOLPHIN MORTALITY IN THE EASTERN TROPICAL PACIFIC TUNA PURSE SEINE FISHERY

Each year the purse seine fishery for yellowfin tuna, *Thunnus albacares*, in the eastern tropical Pacific is responsible for the incidental kill of thousands of small cetaceans,[1] primarily dolphins or "porpoise." Yellowfin tuna are often associated with small cetaceans in this region and fishermen have used this association since 1959 to catch tuna (McNeely 1961; Perrin 1969; Fox 1978). During the purse seining operation, cetaceans encircled with yellowfin tuna by the net may become entangled and accidentally drown. In such cases, the fishermen retain the tuna and discard the cetaceans at sea.

The Marine Mammal Protection Act of 1972 requires the tuna fishery to be managed so that the dolphin populations are maintained at specific population levels and that incidental mortality be reduced to insignificant levels. The National Marine Fisheries Service (NMFS) has the responsibility of monitoring the dolphin mortality and of assessing the impact of dolphin mortality on dolphin populations. NMFS carries out research on the abundance and distribution of dolphins, their biology, the level of incidental mortality, and methods for reducing incidental mortality.

Beginning in 1971, the NMFS regularly placed observers on purse seiners to collect data on the incidental mortality of dolphins. Prior to 1974, however, only a few observers were hired to collect data; the amount of data collected, therefore, is too small to produce a precise estimate of total incidental mortality. Most estimates from this period place the total at about 300,000 to 500,000 animals/yr. Estimates for 1974 and 1975, which are more precise, are 140,000 and 157,000 animals killed, respectively, for the U.S. fleet (Smith[2]).

After a U.S. District Court ruling in 1976, the NMFS set an annual quota of 78,000 animals for

[1]Dolphin, in this paper, is used as a general term referring to all small cetaceans impacted in the fishery. Mortality or kill refers to dolphin mortality incidental to the catch of yellowfin tuna. The unit of fishing effort "set" is defined as a single deployment of a purse seine net around an aggregation of dolphin or tuna. Tuna catches are expressed in the unit short tons, as it is the most common form in which these statistics are reported.

[2]Smith, T. D. Report of the status of porpoise stock workshop. Southwest Fish. Cent. Adm. Rep. LJ-79-41, 120 p.

1976 as the maximum allowable kill by the U.S. tuna fishery. Methods for monitoring the mortality levels, and projecting when the quota would be reached during the year, were required. A yellowfin tuna quota (175,000-195,000 short tons) managed by the Inter-American Tropical Tuna Commission (IATTC), around which the tuna fishermen planned their fishing operations, was also in effect and had to be incorporated into the procedure. In this paper, we describe statistical methods which have been used to estimate the annual incidental dolphin mortality for the U.S. fleet during the year and at the end of the year since 1976. This estimative procedure has been used also for foreign fleets by IATTC since 1979 (Allen and Goldsmith 1981).

Methods

The data sources used to monitor and estimate incidental dolphin mortality were the scientific observer program of the NMFS and the logbook records of the IATTC.

The NMFS observer program provides data on discarded dolphins. Trained technicians were placed aboard a random sample of U.S. tuna vessels to collect data of various types, including number of dolphins killed in a set, amount of tuna caught, species of tuna, fishing location, vessel capacity, and duration of trip.

The IATTC maintains a logbook system whereby it collects data on type of set, fishing locations, tonnage of catch, species of tuna, vessel carrying capacity, and other information that are recorded in logbooks by fishermen.

Three mortality rates were used to estimate total dolphin mortality. They were obtained by dividing the total observed kill of dolphins by the total observed number of dolphin sets (kill-per-set), by the total observed number of days-at-sea (kill-per-day), and by the observed total catch of yellowfin tuna associated with dolphin (kill-per-ton).

Estimation Procedures

Three estimation procedures were used in this study. The first procedure was based on kill-per-day statistics to monitor the dolphin mortality during the year; the second was based on kill-per-ton combined with kill-per-day to project the closure date; and the third was based on kill-per-set to estimate the total mortality at the end of the year.

The kill-per-day and the kill-per-set methods were based on stratified ratio estimators. Trips from which the dolphin set data were taken, were stratified according to fishing locality, vessel carrying capacity, yellowfin tuna catch, gear type, and fishing time. The fishing locality and time were directly related to the IATTC's yellowfin tuna regulatory system, which includes 1) an annual quota on yellowfin tuna catch within the Commission's yellowfin regulatory area (CYRA) (Fig. 1), 2) season closure to enforce the quota on yellowfin tuna catch, and 3) a "last trip" allocated at season closure to each vessel that fished during the open period (Table 1).

Kill-Per-Day Method

The kill-per-day method requires all trips to be stratified according to gear type, vessel carrying capacity, and fishing time; this method was developed to monitor kill during the season. The year was divided into three periods, each designating a trip type. Trip-type 1 included all vessel

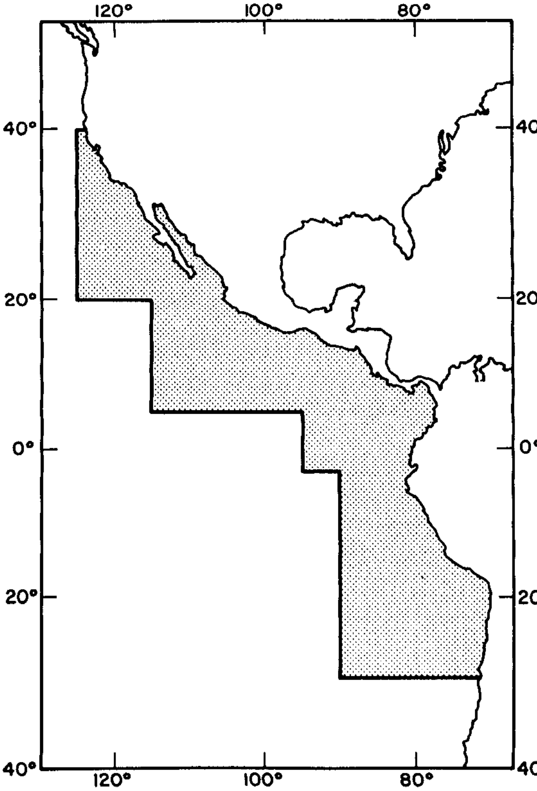

FIGURE 1.—The major part of the Inter-American Tropical Tuna Commission Yellowfin Regulatory Area (Courtesy of IATTC).

days through the IATTC season closure date (1 January through 26 March); trip-type 2 included all vessel days approximately corresponding to the "last trip" (27 March through 4 July); and trip-type 3 contained all vessel days after 4 July. This stratification of time was used to preclude overlapping trips. When a trip crossed a stratum boundary, it was assigned to more than one stratum. For example, for a trip lasting from 1 March to 5 May, the days from 1 March to 26 March would be assigned to trip-type 1, and days from 27 March to 5 May assigned to trip-type 2 (Table 1).

TABLE 1.—Layout of stratification of vessel trips (sets) for kill-per-day and kill-per-set methods.

Kill-per-day method with maximum 30 strata: 15 for each gear type				
NMFS vessel class	Trip 1 1 Jan.-26 Mar.	Trip 2 27 Mar.-4 July open[1] regulated	Trip 3 5 July-end of fishing open[2] regulated	
I				
II				
III				

Kill-per-set method with maximum 32 strata				
IATTC vessel class	Successful sets		Unsuccessful sets	
	Inside CYRA	Outside CYRA	Inside CYRA	Outside CYRA
1				
2				
3				
4				
5				
6				
7				
8				

[1]Trips not subject to IATTC season closure. Most of them were "last trips."
[2]"Last trips" or trips made outside of CYRA.

The statistical formulation for dolphin mortality estimation according to a stratified ratio estimator is as follows (Cochran 1977):

For the ith stratum, $i = 1, \ldots, I$,
let N_i = total number of vessel trips
n_i = number of observed trips
X_{ij} = kill for the jth observed trip $j = 1, \ldots, n_i$
Y_{ij} = days-at-sea for the jth observed trip
r_i = kill-per-day
s_{r_i} = the approximate sample standard error of r_i (kill-per-day)
M_i = total number of days-at-sea
$\hat{T}_i$ = estimated total kill

then
$$r_i = \frac{\sum_j X_{ij}}{\sum_j Y_{ij}} \tag{1}$$

$$s_{r_i}^2 = \frac{N_i - n_i}{N_i} \frac{r_i^2}{n_i} \left(\frac{s_x^2}{\overline{X}_i^2} + \frac{s_y^2}{\overline{Y}_i^2} - 2 \frac{\mathrm{cov}\,(X,Y)}{\overline{X}_i\,\overline{Y}_i} \right)$$

where
$$s_x^2 = \frac{\sum_j (X_{ij} - \overline{X}_i)^2}{n_i - 1}$$

$$s_y^2 = \frac{\sum_j (Y_{ij} - \overline{Y}_i)^2}{n_i - 1}$$

and

$$\mathrm{cov}\,(X,Y) = \frac{\sum_j (X_{ij} - \overline{X}_i)(Y_{ij} - \overline{Y}_i)}{n_i - 1}$$

$$\hat{T}_i = r_i M_i$$

$$\hat{T} = (\Sigma \hat{T}_i) = \Sigma r_i M_i$$

$$s_{\hat{T}}^2 = \Sigma M_i^2\, s_{r_i}^2 .$$

The ratio estimator (r_i) and its approximate sample variance ($s_{r_i}^2$) are unbiased only under certain conditions (Cochran 1977). Alternative variance formulas have been suggested to correct the bias (Royall and Eberhardt 1975; Royall and Cumberland 1981). We chose the commonly used variance formula ($s_{r_i}^2$) in our procedure because the results of a simulation study showed that the bias of the ratio estimator and the approximate variance is negligible (Lo[3]). The simulation study was based upon the empirical dolphin mortality data collected in 1977.

Beginning on 30 June 1976, NMFS observers radioed their mortality counts to a shore base each month (starting in 1977, estimates were made biweekly). Data from this source were used to estimate cumulative mortality and to project the date when the annual quota would be reached.

Combined Kill-Per-Day and Kill-Per-Ton Method

The method using combined kill-per-day and kill-per-ton was developed to project at the end of

[3]Lo, N. C. H. Simulated results of a commonly used ratio estimator applied to incidental dolphin mortality by U.S. tuna purse seiners in the eastern tropical Pacific. Manusc. Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, La Jolla, CA 92038.

each month the date on which the quota would be reached. It included two procedural steps:

1. A series of cumulative dolphin mortality estimates for each future month was made by summing the current total mortality, based on kill-per-day statistics, and the projected mortality for future months, based on kill-per-ton statistics.

To calculate the projected cumulative mortality in future month m, we denote, at the end of month h,

$\hat{T}_h$ = the estimated current total mortality from the observed data by kill-per-day method
$\hat{T}_{m,h}$ = the projected cumulative mortality at the end of month m based upon T_h
U_m = the tonnage of yellowfin tuna catch in month m
$\hat{U}_m$ = the historical monthly tonnage average of yellowfin tuna catch
Z_W = observed kill-per-ton weighted by number of vessels of two gear types.

We then have

$$\hat{T}_{m,h} = \hat{T}_{m-1,h} + U_m \cdot Z_W \doteq \hat{T}_{m-1,h} + \hat{U}_m Z_W$$

$$= \hat{T}_h + \left(\sum_{i=h+1}^{m} \hat{U}_i\right) Z_W$$

for $m = h + 1, h + 2, \ldots, 12 \quad 1 \leq h \leq 11$

and $s^2_{\hat{T}_{m,h}} \doteq s^2_{\hat{T}_h} + \left(\sum_{i=h+1}^{m} \hat{U}_i\right)^2 s^2_{Z_W} + Z^2_W \sum_{i=h+1}^{m} s_i^2$

where s_i^2 is the sample variance of yellowfin tuna catch for month i, and h refers to the month when the up-to-date total mortality was estimated, with the assumption that cov (Z_W, ΣU_i) and cov (U_i; U_j) for $i \neq j$ are negligible. $s^2_{\hat{T}_{m,h}}$ is an approximate sample variance of $T_{m,h}$ by the Delta method (Seber 1973). $s^2_{Z_W}$ is the variance of weighted kill-per-ton. Z_W and $s^2_{Z_W}$ are based on the formulas of the ratio estimator (Equation (1)).

2. For quota Q, the projection of closure date was calculated as follows. If $Q < \hat{T}_{12,h}$, the month g was chosen where $\hat{T}_{g-1,h} < Q < \hat{T}_{g,h}$. The projected date ($V$) in month g was then obtained as:

$$V = \frac{Q - \hat{T}_{g-1,h}}{\hat{T}_{g,h} - \hat{T}_{g-1,h}} \cdot V_g$$

$$= \frac{Q - \left(\hat{T}_h + Z_W \sum_{i=h+1}^{g-1} \hat{U}_i\right)}{\hat{U}_g \cdot \hat{Z}_W} \cdot V_g$$

where V_g is the number of days in month g.

Kill-Per-Set Method

The kill-per-set method was developed to estimate the annual mortality at the end of the year. It requires that all dolphin sets be stratified in three ways: tonnage of yellowfin tuna catch during dolphin set, vessel carrying capacity, and fishing location (Table 1). Time of the year was not a separate factor as it correlated closely with fishing location.

The kill-per-set method was formulated in the same manner as the kill-per-day method (Equation (1)), except the auxiliary variable Y_{ij}'s were observed sets, r_i was kill-per-set, and M_i was total number of sets. In addition, the estimated total dolphin mortality was corrected for nonreporting in IATTC logbooks, inside and outside the CYRA, by a factor C, where C is the ratio of tonnage of yellowfin tuna taken with dolphin which were landed and weighed at port, to the tonnage of yellowfin tuna recorded in the logbooks as an estimate at sea. The mortality for strata without observed data was estimated with the kill-per-set of adjacent vessel-class strata. The resulting sample statistics are in Table 2.

TABLE 2.—Sample statistics[1] of kill-per-set method for 1976 U.S. purse seine tuna fleet.

IATTC vessel class	Inside CYRA			Outside CYRA		
	r_i	$S^2_{r_i}$	$X(n_i)$	r_i	$S^2_{r_i}$	$X_i(n_i)$
Successful sets:						
1	—	—	—	—	—	—
2	4.00	—	1(1)	—	—	—
3	—	—	—	—	—	—
4	3.02	2.17	68(5)	13.60	41.94	88(4)
5	7.08	4.42	37(4)	43.90	277.76	62(4)
6	10.60	15.51	44(4)	26.70	—	6(1)
7	17.60	7.72	148(1)	12.90	26.58	140(12)
8	22.00	19.62	32(2)	1.00	—	1(1)
Unsuccessful sets:						
1	—	—	—	—	—	—
2	0	—	1(1)	—	—	—
3	—	—	—	—	—	—
4	4.59	12.70	22(6)	9.90	22.95	10(3)
5	0.90	0.15	20(5)	4.50	8.24	8(2)
6	16.40	320.16	14(5)	8.31	27.91	—
7	3.15	0.28	20(4)	12.10	107.27	8(5)
8	3.27	7.78	22(2)	0	—	1(1)

[1] r_i = kill-per-set, $S^2_{r_i}$ = sample variance of r_i, X_i = number of observed dolphin sets, n_i = number of observed trips.

Results

The estimated mortality based on the kill-per-day method for each of the three periods was 24,000 animals (SE = 5,400) (1 January-26 March), 29,000 animals (SE = 5,300) (27 March-4 July), and 53,000 animals (SE = 21,000) (5 July-end of fishing), to give a total kill of 105,000 animals (SE = 22,000) for 1976 (Table 3).

Using the kill-per-set method, we computed dolphin mortality estimates adjusted for nonreporting of sets inside and outside the CYRA (Table 4). The estimated total dolphin mortality with this method was 104,000 animals (SE = 13,000).

The closure dates for reaching the quota of 78,000 animals as projected at the end of June, July, and September were in October. The fishery itself, however, was not actually closed until November, after a court hearing process.

The annual quotas for 1977, 1978, and 1979 were 52,000, 42,000, and 31,000 animals, respectively, and the mortality was monitored biweekly by species/stock. Due to the improvement and use of rescue techniques by the fishermen and the motivation of tuna fishermen to reduce dolphin mortality, the kill-per-day estimates of most of the species/stock have been below their annual quotas. The kill-per-set estimate for annual total dolphin mortality by U.S. seiners for 1977, 1978, and 1979 was 24,000 (SE = 3,500), 19,000 (SE = 3,700) and 18,000 animals (SE = 2,200), respectively.

Discussion

Procedures for estimating dolphin mortality have used the basic models tailored to suit the existing conditions of the fishery and available monitoring resources since 1976. The number of strata for the kill-per-day method has been reduced because only vessel classes II and III are fishing tuna with dolphin (the majority being class III vessels), and all the vessels are required to use a standard gear, i.e., super apron. Moreover, since 1979, there has been no quota on the yellowfin tuna catch. Thus, the entire year is "open" for fishing (Table 1).

The kill-per-set method is more precise than the kill-per-day method because the standard error is smaller. However, in order to make during-the-year estimates, procedures to collect accurate information on the number of dolphin sets for the whole fleet at regular intervals during the year, yet need to be developed. Analysis of use of the kill-per-set method indicated that the number of vessel classes (eight) was unnecessarily large. A revision of the stratification scheme for this method is currently in progress.

The statistical techniques of monitoring and estimating dolphin mortality can be applied to other kinds of incidental catches. The 1976 dolphin mortality data, in particular, demonstrated the complexity of the situation where the selection of auxiliary variables for ratio estimator and the stratification of data to reduce the variance were not straight forward. These factors have to be taken into account to ensure high precision of the estimates.

TABLE 3.—Estimated kill by U.S. vessels in 1976 using kill-per-day method.

	1 Jan.-26 Mar.		27 Mar.-4 July		5 July-end of fishing		1 Jan.-end of fishing	
Gear type	Kill	SE	Kill	SE	Kill	SE	Kill	SE
Conventional	23,769	5,448	24,884	5,316	47,068	20,531	95,721	21,896
Experimental	144	—	3,764	440	5,727	1,931	9,635	1,980
Total	23,913	5,448	28,648	5,334	52,795	20,622	105,356	21,985

TABLE 4.—Estimated kill by U.S. vessels in 1976 corrected for nonreported sets (SE in parentheses) using kill-per-set method.

Area	Tons YF on dolphin landed[1]	Tons YF on dolphin logged[1]	Correction factor C Column 2 ÷ column 3	Adjusted kill
CYRA	55,112	47,180	1.17	44,061 (4,424)
Outside	70,745	65,248	1.08	55,801 (12,690)
Total				99,862 (13,439)
Experimental and chartered vessels				4,211 (—)
Grand total				104,073 (13,439)

[1]IATTC record.

Literature Cited

ALLEN, R. L., AND M. D. GOLDSMITH.
1981. Dolphin mortality in the eastern tropical Pacific incidental to purse seining for yellowfin tuna, 1979. Rep. Int. Whaling Comm. 31:539-540.

Cochran, W. G.
1977. Sampling Techniques. 3rd ed. Wiley, N.Y., 428 p.
Fox, W. W., Jr.
1978. Tuna-dolphin program: five years of progress. Oceans 11(3):57-59.
McNeely, R. L.
1961. Purse seine revolution in tuna fishing. Pac. Fisherman 59(7):27-58.
Perrin, W. F.
1969. Using porpoise to catch tuna. World Fishing 18 (6):42-45.
Royall, R. M., and W. G. Cumberland.
1981. An empirical study of the ratio estimator and estimators of its variance. J. Am. Stat. Assoc. 76:66-77.
Royall, R. M., and K. R. Eberhardt.
1975. Variance estimates for the ratio estimator. Sankhyā, Ser. C, 37:43-52.
Seber, G. A. F.
1973. The estimation of animal abundance and related parameters. Hafner Press, N.Y., 506 p.

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WHITE DALL'S PORPOISE SIGHTED IN THE NORTH PACIFIC

Several studies on the population and distribution of marine mammals were conducted between 1978 and 1981 in the North Pacific Ocean under a United States-Japan cooperative agreement of the International Convention for the High Seas Fisheries of the North Pacific Ocean. During that period, two white Dall's porpoise, *Phocoenoides dalli*, were sighted.

Two of the authors (Joyce and Ogasawara) sighted one such color variant (Fig. 1) at 1410 h (JST) on 29 July 1980, 8 km south of Kushiro, Japan (lat. 42°52. 5′N, long. 144°21.5′E), while aboard the RV *Hokushin Maru.* The water depth was 70 m and the sea surface temperature was 17.5°C. The animal was estimated to be 190 to 210 cm long and was accompanied by a normally colored Dall's porpoise, dalli type, of the same size. Both animals approached the vessel and rode the bow wave for 5 min. The white animal surfaced once every 5 to 6 s and created a "roostertail" splash, typical of the Dall's porpoise. It was completely white except for a slight gray shading along the dorsal ridge between the dorsal fin and the flukes, and along the posterior edge of the blowhole. There was no color differentiation where the black-white border usually occurs on the lateral surface. Other than color, there were no physical or behavioral characteristics to distinguish this animal from other Dall's porpoise.

Another white Dall's porpoise was sighted by Rosapepe on 13 August 1980, 25 km west of the Washington State coast (lat. 45°26.5′N, long. 124°15.6′W), while aboard the NOAA vessel *Miller Freeman.* The animal was all white except for a brownish area on the dorsal surface, between the blowhole and the dorsal fin. It was seen with three Dall's porpoises, dalli type, of normal coloration. All four animals approached the vessel and rode the bow wave for 7 min.

The Dall's porpoise is known to exhibit two and possibly three color variations (Morejohn 1979). The dalli type, the original type described, is mostly black, with a white area on the ventral and lower lateral surfaces, originating in line with the anterior insertion of the dorsal fin and extending posterior of the genital slit (True 1885). The truei type is differentiated by the anterior extension of the white area to the anterior insertion of the pectoral flipper (Andrews 1911). The truei type was once classified as a separate species by Andrews (1911) but was later described as a color variant (Cowan 1944). The taxonomic status of this type is still in question. All black Dall's porpoise have been described (Wilke et al. 1953; Nishiwaki 1966), as has the gray or striped variant (Wilke et al. 1953; Morejohn et al. 1973). However, the white variant has not previously been described, indicating that this colormorph, possibly caused by albinism, occurs rarely.

Acknowledgments

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