Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes

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Abstract.—Bottom longline and baited video camera operations were conducted at 39 stations off the Hawaiian Islands of Oahu, Maui, and Kauai during 1992. Objectives of the 1992 cruise were to assess the precision, accuracy, and efficiency of a video camera system versus a traditional abundance index (longline catch per unit of effort [CPUE]) for juvenile pink snapper ("opakapaka"), *Pristipomoides filamentosus*, a commercially important eteline snapper in Hawaii. Precision of the video samples was reevaluated with data from 18 stations sampled during 1993 off Kaneohe Bay. The video index of the maximum number of opakapaka observed (MAXNO, the natural log-transformed mean of three camera drops) was best correlated with the log of longline CPUE (r=0.79, P<0.001, n=15). Variation in the data for video MAXNO was nominally less than that of the longline CPUE. No monotone trend over stations was noted in samples from 1993. Sample sizes of 33 stations for longline and 18 stations for video would be necessary to detect twofold changes in abundance of opakapaka at a site, based on our analysis of the two end positions of the 10 windward Oahu stations that had three quantitative deployments. Reanalysis of power with data from the 1993 cruise indicates that a sample size of approximately 22 stations (α_2=0.05) or approximately 17 stations (α_2=0.1) would be necessary to detect twofold changes.

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Deep-water snappers (family: Lutjanidae) support an important commercial fishery around the main Hawaiian Islands (MHI) and the Northwestern Hawaiian Islands (NWHI). Pink snapper (or "opakapaka"), *Pristipomoides filamentosus*, has been one of the most important species in terms of landings (20–30% of total weight) and revenue for many years[1] (Ralston and Polovina, 1982; WPRFMC[2]). Research on adult *P. filamentosus* has included studies on sexual maturity and growth (Ralston and Miyamoto, 1983; Kikkawa, 1984; Okamoto[3]), trophic ecology (Parrish, 1987; Haight et al., 1993); distribution (Kami, 1973; Moffitt, 1980); habitat (Ralston et al., 1986; Moffitt et al., 1989); and mortality (Ralston, 1987). Relatively few larval and pelagic juvenile specimens of opakapaka have been collected; therefore, little is known of their early life history (Leis, 1987).

Exploratory research on recruited, epibenthic juvenile *P. filamentosus* has been conducted by the Honolulu Laboratory of the National Marine Fisheries Service (NMFS) since 1988. This has included initial habitat description[4] and work on age and growth of juveniles at Kaneohe Bay, Oahu (Parrish, 1989; DeMartini et al., 1994). Recent work has focused on evaluating techniques for assessing the distribution and abundance of juvenile opakapaka in Hawaiian waters. Characterizations of juvenile opakapaka abundance based on rod and reel, handlines, and bottom trawls, however, are either biased, imprecise, or destructive of habitat.[5]

[1] Kawamoto, K. E. 1992. Northwestern Hawaiian Islands bottomfish fishery, 1991. Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822–2396. Southwest Fish. Sci. Cent. Admin. Rep. H-92-12, 20 p.

[2] WPRFMC (Western Pacific Regional Fisheries Management Council). 1992. Bottomfish and seamount groundfish fisheries of the Western Pacific region, p. 57–71. 1991 Annual Report for the WPRFMC, Honolulu, HI 96813.

[3] Okamoto, H. Y. 1993. Project to develop opakapaka (pink snapper) tagging techniques to assess movement behavior. Sept. 1, 1990 to Aug. 31, 1992. Final Rep. of HI. Dep. Land and Nat. Res. (HDLNR) to NOAA., Award no. NA90AA-D-IJ466. HDLNR, DAR, Honolulu, HI 96814, 18 p.

[4] Moffitt, R. B., and F. A. Parrish. In review. Habitat use and life history of juvenile Hawaiian pink snappers, *Pristipomoides filamentosus*. Bull. Mar. Sci.

[5] Ellis, D. M., E. E. DeMartini, and R. B. Moffitt. 1992. Bottom trawl catches of juvenile opakapaka, *Pristipomoides filamentosus* (F. Lutjanidae), and associated fishes, *Townsend Cromwell* cruise TC-90-10, 1990. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Sci. Cent. Admin. Rep H-92-03, 33 p.

Still and video cameras (baited and unbaited) have been used to sample other marine habitats, e.g. to compare data collected with other methods and to reduce biases associated with remote collection techniques (Uzmann et al., 1978; Grimes et al., 1982; Matlock et al., 1991; Moffitt and Parrish, 1992), and to study the natural history and estimate the abundance indices of different species (Miller, 1975; Priede et al., 1990; Auster et al., 1991; Armstrong et al., 1992; Michalopoulos et al., 1992). Baited video systems have some inherent biases (such as loss of odor attractant (or bait; Isaacs and Schwartzlose, 1975), and intra- or inter-specific competition for bait (Armstrong et al., 1992). Towed video systems and remotely operated vehicles (ROV's) have been used to collect analogous data without the use of bait. A towed system or ROV can sample a known area and assess organismal densities directly within that area. Although a towed and unbaited video system might be preferable if the objective is to estimate absolute fish density, we chose a stationary, baited system both in order to minimize the disturbance of bottom habitat and to provide an index of relative abundance similar to catch per unit of effort (CPUE) that would be sufficient for temporal comparisons.

In this paper, we assess the precision, accuracy, and efficiency of a baited video camera system for producing indices of fish abundance based on a visual record, and we compare these video data with a more traditional abundance index of longline CPUE. We first compared the two methods by pair-sampling during an initial cruise in 1992. Preliminary estimates of video precision were made with these data. Power and sample sizes for video sampling were again estimated with data obtained during 1993. Effects of station and depth for the 1993 cruise were also examined. We emphasize data for the target species, opakapaka, but include complementary data for Bleeker's balloonfish ("puffers"), *Torquigener florealis*, because of its numerical dominance in both types of samples.

Materials and methods

Sampling

Simultaneous longline and video camera operations were conducted for four days offshore of windward Oahu embayments (Fig. 1) and three days offshore of embayments at each of two other islands (Maui and Kauai) during a May 1992 cruise of the NOAA ship *Townsend Cromwell*. Additional video camera operations were conducted from small craft during May 1993 outside Kaneohe Bay, Oahu (Fig. 1). Sampling was conducted on flat, unconsolidated bottoms (Parrish, 1989; Moffitt and Parrish[4]) between 0800 and 1530 hours. Longline depths ranged from 54 m to 107 m and video camera depths ranged from 52 m to 87 m for the 1992 cruise, the approximate depth range for juvenile opakapaka (Parrish 1989; Ellis et al.[5]). Paired video-longline samples were collected in 1992 over a longshore spatial scale of 10 nmi (18.5 km) off Oahu (Fig. 1). The longshore spatial scales for Kahului Bay, Maui, and Hanalei Bay, Kauai, were 9.1 nmi (16.9 km) and 9.5 nmi (17.6 km), respectively. From one to three video deployments were made per station at shallow, mid-, and deep depths along the longline set. A total of 39 longline and video stations were completed (15 at Oahu, and 24 combined for Maui and Kauai). A complete set of three (shallow, mid-, and deep) video camera deployments were completed per station for 10 of the 15 stations off Oahu. In 1993, video sampling was refocused on a finer spatial scale (2.4 nmi or 4.4 km) off Kaneohe Bay, Oahu, over known bottom topography to increase the probability of sampling more homogeneous habitat. Two video deployments per station were made at shallow (73 m to 77 m) and deep (83 m to 85 m) positions in 1993. A total of 18 stations were completed in 1993.

Video camera and longline stations were parallel within 50 to 75 m of each other. The spacing between video-longline stations during any particular day was approximately 1 km (0.5 nmi) longshore during 1992. Spacing between video deployments was approximately 100 to 300 m. Longshore distance between video stations in 1993 was about 200 m (0.1 nmi). At distances of ≥100 m separating adjacent stations, successive video deployments were likely independent, because the greatest distance of fish attraction to the bait was only 48 to 90 m. This estimate was based on average maximum bottom current speeds of 0.1 to 0.2 m/s respectively (Bathen, 1978), a soak time of 10 minutes, and a swimming speed for opakapaka of 0.6 m/s (or approximately 3 body lengths (BL) per second, where one BL=20 cm; Videler, 1993). Depths of all video and longline sets were determined by depth sounders aboard the research vessels, and positions were determined by GPS (Global Positioning System) or sighting compass, as Loran-C capabilities were unavailable.

Longlines were deployed approximately perpendicular to depth contours. Bottom longline operations used modified Kali longlines,[6] each with 30 individu-

[6] Shiota, P. M. 1987. A comparison of bottom longline and deep-sea handline for sampling bottom fishes in the Hawaiian Archipelago. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-87-5, 18 p.

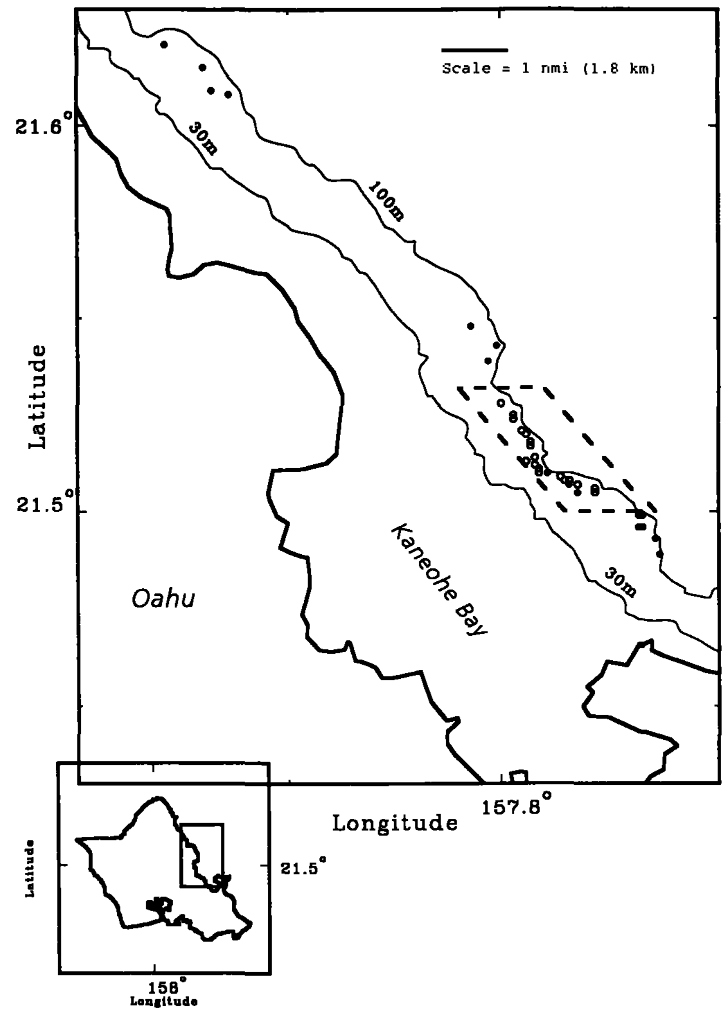

Figure 1

Area of operations off Kaneohe Bay, Oahu, for video and longline surveys for opakapaka, *Pristipomoides filamentosus*. Stations for video and longline in 1992 are midpoints identified by solid circles. Area of video coverage in 1993 is enclosed within the dotted lines and stations are midpoints identified by hollow circles.

ally weighted and buoyed 3-m PVC droppers. Droppers were attached along the main line about 18 m apart. A 9.07-kg test, hard monofilament branch leader and a 3.63-kg test, hard monofilament hook leader were used. Each dropper had five leaders with size–12 Izuo circle hooks (AH style), for a total of 150 hooks per longline set. Stripped squid was used as bait. The standard soak time was 30 minutes, and three to four sets were completed each day.

Two separate, 8-mm video camera assemblies were used for the video operations. Each video camera was equipped with a No. 1 diopter magnification lens and a wide angle zoom lens with a red filter for underwater correction. Camera focus, sensitivity, and white balance were manually adjusted, but an automatic aperture setting was used. The focus distance for both video cameras was fixed at 2.13 m, and the focal length of the lens was set at 11 mm. Each video camera was enclosed in an underwater housing and secured in a weighted frame (Fig. 2). A single, 15-cm long bait container was positioned 60 cm in front of the camera lens and mounted on a PVC rod. The bait container held a single (≈0.5-kg) mackerel (*Scomber* sp.) and one whole squid (*Loligo* sp.) tie-wrapped to the outside, both of which were changed after each deployment. The camera assemblies were manually

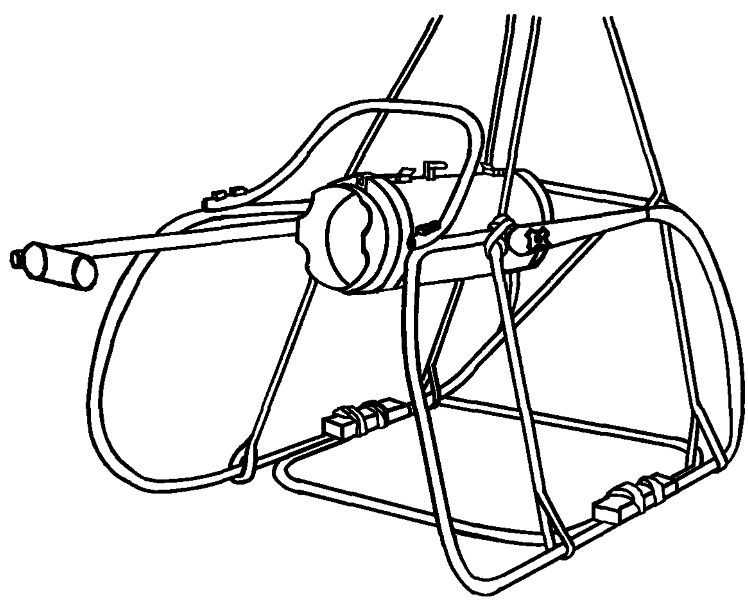

Figure 2
Baited video camera assembly with bait container positioned 60 cm in front of the camera lens.

lowered to the bottom and marked by a buoy; later they were raised to the surface by outboard engine power. Cameras were allowed to rest on the bottom for a standard interval of 10 minutes before retrieval.

The duration and number of video camera deployments to be used on the ship cruise were estimated on the basis of three earlier pilot deployments of the video assembly from small craft. These prior tests indicated that about 10 minutes were required to deploy and retrieve the camera assembly. The time to first appearance (TFAP) of opakapaka from the three pilot stations was 227 ± 300 sec (mean ± 1 standard deviation of the data [SD]) after bottom contact. A bottom time of 10 minutes was chosen to accommodate likely extremes and also to allow 6 deployments per 2-h tape (20 min per deployment × 6 deployments). With two cameras, 12 deployments per day could be made without changing tapes. The maximum number of longline sets was limited to four per day, based on three camera deployments per longline set.

Types of data

Species presence, total number of individuals per species, and the number of hooks lost were recorded for each longline set. Species presence and duration of squid bait attachment to the bait container (BTM) were recorded for each video sequence. In addition, for each video sequence, three indices of abundance were scored for each species taped: maximum number (MAXNO); time to first appearance (TFAP); and total duration in sequence (TOTTM). The MAXNO index was determined as the peak number of a species visible at any one time (maximum interval one second) during a deployment. Fork length (FL) to the nearest 0.1 centimeter (cm) was recorded for fish caught on the longline. The FL of opakapaka observed on video was estimated and rounded to the nearest 5 cm by comparing fish swimming in the plane of the bait container with the known size of the container.

Statistics

An average maximum number of fish recorded for data collected in 1992 was calculated for each of nine sequences (three video stations) by using a mean weighted by the duration of each occurrence:

$$\overline{X}_W = \frac{\sum_{h=1}^{n} X_h \cdot N_h}{N}, \tag{1}$$

where $\overline{X}_W$=the weighted average maximum number of fish, n=total number of occurrences, X_h= maximum number of fish seen in the h^{th} occurrence, N_h=duration (s) of the h^{th} occurrence, and $N=\sum N_h$= 600 s.

Video indexes were calculated as means (of up to 3 deployments) to standardize for multiple deployments per station. Video indices were derived in two logarithmic forms—mean of logs (*ML*),

$$ML = \frac{\sum_{i=1}^{n} \ln(x_i + 1)}{n}, \tag{2}$$

and log of means (LM),

$$LM = \ln\left[\left(\frac{\sum_{i=1}^{n} x_i}{n}\right) + 1\right], \tag{3}$$

where x_i = individual datum for a variable (i.e., the value for the variable MAXNO, TFAP, or TOTTM for each deployment at a station) and n=number of deployments per station. The longline index consisted of log-transformed individual set data [ln (catch +

1)]. The number of stations where each species was caught or seen was also tallied for each gear type. For nonzero mean data collected in 1993, the best form of the video index (*LM'*, see Results section), was calculated as follows:

$$LM' = \ln\left[\left(\frac{\sum_{i=1}^{n} x_i}{n}\right)\right], \tag{4}$$

where x_i = individual datum for MAXNO and n=number of deployments per station.

A matrix of Pearson's correlation coefficients was calculated for 1992 data (SAS, 1987) with the log-transformed variables to detect interrelationships among all the video and longline indices. Spearman's rank correlations were also calculated and compared. Multiple linear regression (SAS, 1987) was used to estimate the effect of competition between opakapaka and puffers for longline hooks on the basis of the following model:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \varepsilon, \tag{5}$$

where Y=ln (opakapaka video MAXNO), X_1=ln (no. hooks lost + no. puffers caught), and X_2=ln (number of opakapaka caught). The model was run as a forward regression without an intercept and with an entry level for significance equal to $P \leq 0.10$. The precision (repeatability) of video and longline was described by the coefficient of variation (V, Sokal and Rohlf, 1981; Zar, 1984):

$$V = \left(\frac{SD}{\text{mean}}\right) \times 100(\%), \tag{6}$$

where SD is the standard deviation.

Longshore station and relative depth effects for 1993 data were analyzed by using standard parametric and nonparametric procedures (SAS, 1987).

Sample size and power analysis

We evaluated video and longline data in a power analysis for the t-test of means. Specifically, we estimated the sample sizes required to detect a twofold change in abundance by using either sampling method. Skalski and McKenzie (1982) set a precedent for use of the criterion of twofold change in environmental monitoring studies; annual variations much larger than this are typical for marine fishes (Hennemuth et al., 1980; Francis, 1993). The effect size (ES) was calculated as follows:

$$ES = \frac{0.693}{SD}, \tag{7}$$

where 0.693= $|\pm$ twofold difference in $\bar{x}|$ for the natural log ($\bar{x}$) and SD is the standard deviation. Cohen (Tables 2.3.4 and 2.4.1, 1988) was consulted for the requisite sample sizes. The ES for each gear was evaluated at β=0.20, power (1–β)=0.8, and α_2=0.05. For the 1993 data, ES was also evaluated at α_2=0.1.

Results and discussion

Sample composition

The mean time to first appearance (TFAP) of opakapaka for 1992 video tapes with opakapaka present (all islands included) was 203 ±165 (SD) seconds. The total time (TOTTM) of opakapaka during a deployment averaged 122 ± 133 seconds. The maximum number (MAXNO) of opakapaka appeared on tape at approximately 354 (±153) s, based on the nine video sequences for which the weighted average MAXNO ($\bar{X}_W$) was calculated. These data confirm our initial choice of a 10-min bottom time.

In 1992, only windward Oahu data were used for comparisons and statistical analyses, because the opakapaka measures from Maui and Kauai included large percentages (92% and 67%) of "double-zeros" (zero longline catch, zero fish recorded). Catches of *P. filamentosus* also were greatest for the windward Oahu site; 54 of the 58 juvenile opakapaka were longlined off windward Oahu. Puffers were prevalent at windward Oahu and at Maui. Both longlined and video-recorded opakapaka were juvenile size (13 to 21 cm FL, and 15 to 25 cm FL, respectively; Kikkawa, 1984; Moffitt and Parrish[4]).

Frequency of occurrence data and total number of species differed between longline catches and video records (Fig. 3). Puffers ranked first in abundance and opakapaka second in both the longline and video data. Video cameras recorded the presence of opakapaka and puffers more often than did the longlines (Fig. 3). Video tapes also recorded a greater diversity of species (Table 1), suggesting greater accuracy of the video system. Fish that were not caught by the longline but were seen on video included reef-associated species (e.g. pennant butterflyfish, *Heniochus diphreutes*, and whitesaddle goatfish, *Parupeneus porphyreus*, sharks (*Carcharhinus* sp.), and rays (*Dasyatis* sp.). Longlines also undersampled the lizardfish, *Trachinocephalus myops* (Fig. 3), a major component of this deep-water, soft-bottom fish assemblage.[5] No major differences in species composition occurred in video surveys from 1992 and 1993.

1992 video-longline relations

The MAXNO index for opakapaka and puffers was highly correlated with the total duration on film

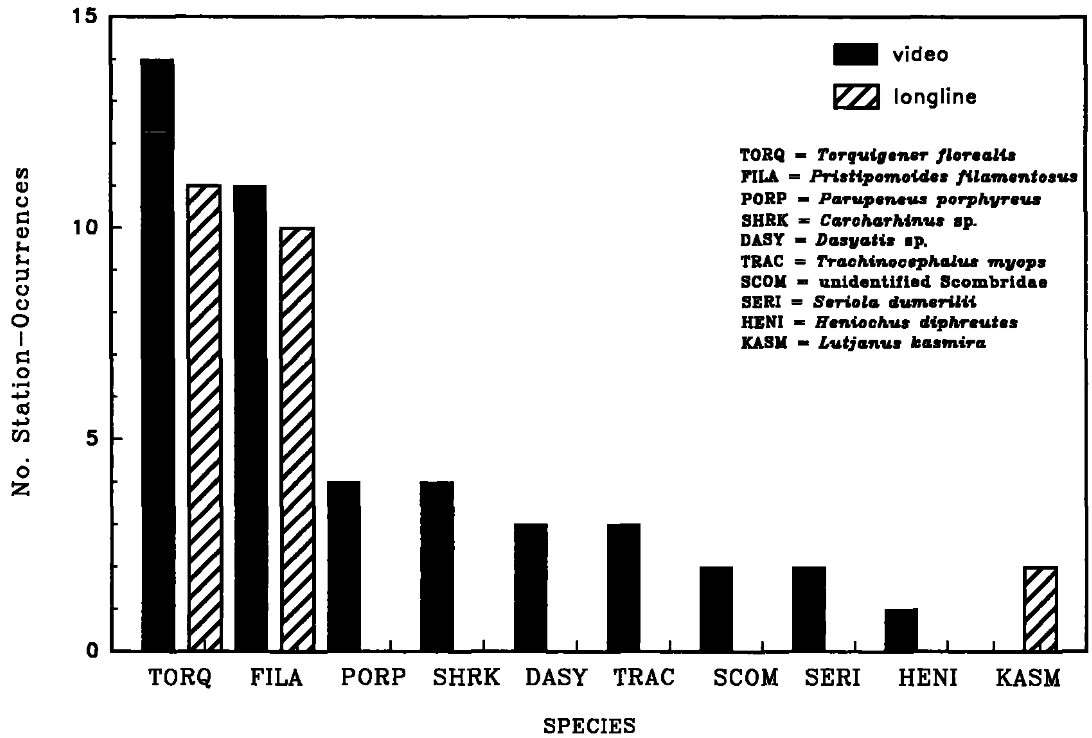

Figure 3

Frequency of occurrence of ten common species on video camera deployments and longline sets conducted during 1992 off windward Oahu (n=15 stations). Refer to Table 1 for common names.

Table 1

Total numbers of fish seen and caught at 15 video and longline stations located off windward Oahu during 1992. Total number for a fish taxon for video stations is the sum of the maximum numbers seen on 38 films. Total number for longline stations is the number of fish caught.

Species	Common names	Video	Longline
Torquigener florealis	Bleeker's balloonfish	221	80
Pristipomoides filamentosus	Pink snapper (opakapaka)	94	54
Heniochus diphreutes	Pennant butterflyfish	25	—
Parupeneus porphyreus	Whitesaddle goatfish	10	—
unidentified Scombridae	Tuna or mackeral	6	—
Trachinocephalus myops	Lizardfish	5	—
Carcharhinus sp.	Shark	4	—
Sphyrna sp.	Hammerhead shark	4	—
Seriola dumerilii	Amberjack	3	—
Dasyatis sp.	Stingray	3	—
Chaetodon miliaris	Milletseed butterflyfish	3	—
unidentified teleosts	Bony fish	2	—
Parupeneus pleurostigma	Sidespot goatfish	1	—
Sufflamen fraenatus	Bridle triggerfish	1	—
Canthigaster rivulata	Maze toby	1	—
Parupeneus sp.	Goatfish	1	—
Lutjanus kasmira	Bluestripe snapper	—	·3

(TOTTM) and time to first appearance (TFAP) of the respective species (Table 2, LM form). The duration of squid bait (BTM index) was significantly correlated with the MAXNO index and the other video indices for opakapaka but was more strongly correlated with the MAXNO index for puffers (Table 2). Videos indicated that puffers were usually responsible for the removal of the squid bait; a direct relationship between puffer numbers and the rate of bait disappearance was evident. Spearman's rank correlations mirrored the parametric correlations.

After log-transformation, the data pairs were approximately bivariate normal. Among all the video indices, MAXNO was best correlated with lnCPUE (LLNO) for opakapaka (Table 2). The ML and LM forms of the MAXNO video index were compared separately with the longline CPUE, and the LM form provided a slight but consistently better Pearson's correlation than did the ML form for both opakapaka and puffers. Therefore, the LM form of the MAXNO index was used for all further parametric comparisons and analyses.

The MAXNO-CPUE relationship was approximately linear (Fig. 4A), and its residual plot showed neither discernible pattern nor slope (P=1.0, Fig. 4B). If all double-zero data are deleted, the correlation between video MAXNO and longline CPUE loses significance (r=0.55, P=0.08, n=11). However, the double-zero data were retained in subsequent analyses because there was no a priori reason to believe they did not represent real absences.

The observed magnitude of hook loss ($\bar{x}$=32%) indicates that longline CPUE is fundamentally inaccurate and biased for sampling this habitat and species assemblage. Apparently, most hook loss occurred when puffers bit through the leader above the hook. Hook competition is often a problem with longlines when hooked fish begin to saturate available hooks (Rothschild, 1967). Removal of hooks has a similar effect. A multiple linear regression with two descriptive variables, a puffer factor (X_1) equal to the number of hooks lost plus puffer catch and opakapaka catch (X_2), was run to determine the effect of puffers on the relation between longline CPUE and the video MAXNO index for opakapaka. X_1 and X_2 were first determined to be uncorrelated (r^2=0.02, P=0.62). The model (Eqn. 5) for the multiple regression was forced through the origin, because neither sampling device could record the presence of fish in its absence. The total variation in the opakapaka video index explained by the model was 87% (R^2=0.87, P<0.001). Opakapaka longline CPUE explained 83% of the variation (r^2=0.83, P<0.001), and the puffer factor explained an additional 4% of the variation (r^2=0.04, P=0.07). The latter observation suggests that the puffer factor might strongly influence video-longline relations for opakapaka at times of relatively high puffer abundance.

Precision for longline and video cameras was separately examined. For both opakapaka and puffers, cameras had nominally but consistently better precision (V=81% and 48%) than did longline CPUE (V=91% and 71%).

Table 2

Correlation between log-transformed mean video indices (LM) and log-transformed longline catch per unit of effort (lnCPUE) from the 1992 windward Oahu site (n=15 stations). Pearson correlation coefficients (r) are displayed above their respective P-values (Prob> $|R|$, H_0: Rho=0) for *Pristipomoides filamentosus* and *Torquigener florealis*. MAXNO = maximum number seen on tape; TOTTM=total duration of a species on tape; TFAP=time to first appearance of a species; BTM=duration of external squid bait; and LLNO=longline CPUE.

	TOTTM	TFAP	BTM	LLNO
Pristipomoides filamentosus				
MAXNO	0.9665	–0.9143	–0.5748	0.7855
	0.0001	0.0001	0.0250	0.0005
TOTTM		–0.8500	–0.5681	0.7285
		0.0001	0.0271	0.0021
TFAP			0.5729	–0.6467
			0.0256	0.0092
BTM				–0.2982
				0.2803
Torquigener florealis				
MAXNO	0.9465	–0.5770	–0.6654	0.5365
	0.0001	0.0243	0.0068	0.0392
TOTTM		–0.6030	–0.5902	0.5932
		0.0173	0.0205	0.0198
TFAP			0.5141	–0.1143
			0.0499	0.6851
BTM				–0.5193
				0.0473

1993 video statistics

The MAXNO video index did not differ between shallow and deep positions (Student's t=0.27, P=0.79; Kruskal-Wallis χ^2=0.09, P=0.76) in May 1993 (Fig. 5). The mean MAXNO data lack a monotone trend over stations (P=0.5), even though raw MAXNO values were atypically large at several stations (χ^2=28.0, P=0.04; Fig. 5). Overall, however, dependence among stations was absent and neither precluded simple t-tests of the means nor power estimates for tests of the means.

Power analysis

Power was estimated for opakapaka abundance indices. Sample sizes for longline and video gear would be limited in practice by the duration and availability of a large research vessel (a maximum of five days at one location) and by estimates of maximum effort attainable for each gear. The latter considered the time needed for deployment, retrieval, and processing of specimens for longlines and the time required for video camera battery and tape changes. The estimated upper limit for sample size was 30 stations (at 6 stations per day) for both the longline and the video cameras; a video station consisted of three camera deployments. All 1992 data from windward Oahu (n=15 stations) were analyzed first. Sample sizes of 26 stations for video and 33 stations for longlines were estimated as necessary to detect a twofold change in numbers of juvenile opakapaka.

Power was next estimated by using only those 1992 windward Oahu stations with the full complement of three deployments (n=10). The variability (V=81%) of the video MAXNO index at these 10 stations (3 deployments inclusive) did not differ from the total Oahu data set. A sample size of 17 stations (51 deployments) was estimated as necessary to detect a twofold change in the MAXNO index, within the practical limit of 30 stations. The estimated sample size for longline, based on data for these same 10 stations, was still 33 stations, slightly over the limit of 30 stations.

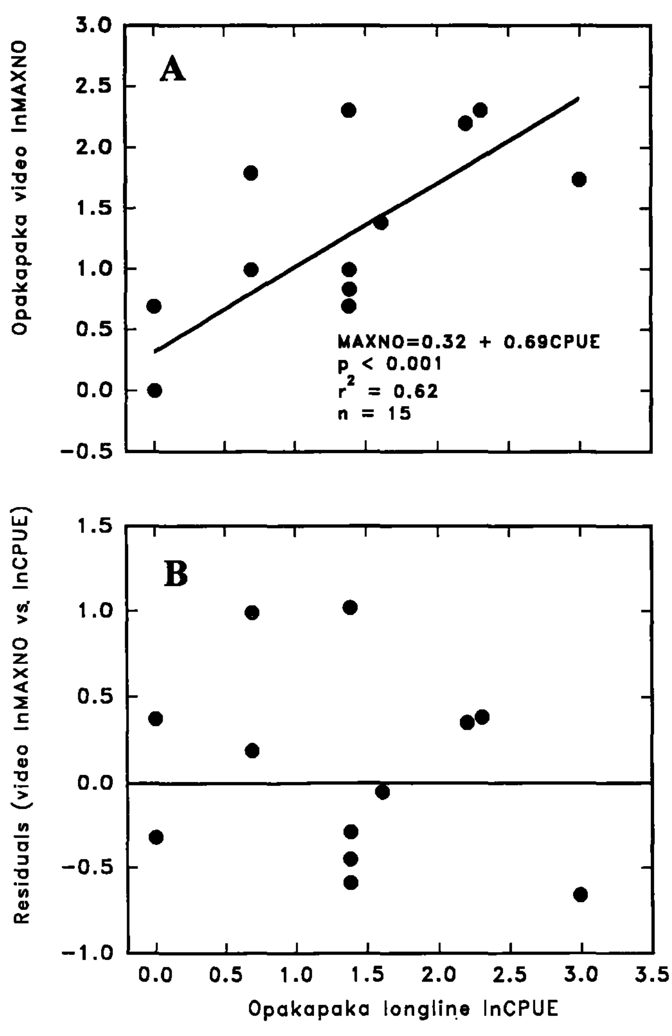

Figure 4

(A) Scatterplot and fitted regression line for the video index maximum number seen (lnMAXNO) and longline lnCPUE for *Pristipomoides filamentosus* (opakapaka) for 1992 data. Four double-zero observations were coincident. (B) Plot of residuals from the video versus longline regression of Fig. 4A versus longline lnCPUE for 1992 data; zero line is included. Four points were coincident as in 4A.

Power was next reexamined to determine the effect of reducing effort to two video deployments per station, rather than to three. By using only the shallow and deep sets of the 10 1992 stations with three complete deployments, variability improved slightly (V=76%), and only 18 stations (36 deployments) were estimated as necessary to detect a twofold change for opakapaka. Video MAXNO remained significantly correlated with longline CPUE for opakapaka by using two deployments per station (r=0.66, P=0.04, n=10).

The 18 pairs of 1993 video data were used to reevaluate power and sample size for a smaller, more homogeneous study area. The LM' form of the video MAXNO index was used to avoid possible bias introduced by adding a constant to the data. The calculations used 17 pairs of deployments because the mean of one data pair was zero, the log of zero being undefined. Variability (V) for the 1993 data improved to 49% with these refinements. Twenty-two stations were estimated as necessary to detect a twofold change in abundance at α_2=0.05. If α_2 were relaxed to 0.1, 17 stations would be necessary to detect a twofold change. In practice, slightly greater numbers of samples would be necessary, because deleting the single zero-mean datum artificially inflated our power estimate. Nonetheless, the 1993 samples provide the best data for evaluating precision that are presently available.

Comparison with other baited camera studies

Previous baited camera studies of deep-sea species (Priede et al., 1990; Armstrong et al.,

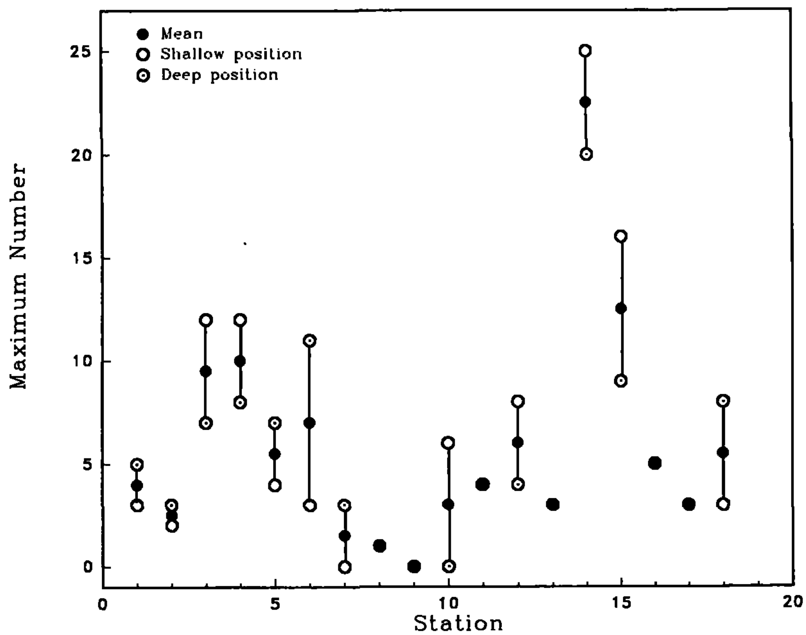

Figure 5

Scatterplot of maximum number of opakapaka observed (MAXNO) for shallow and deep positions and their mean by stations for data collected during May 1993. Stations are ordered in geographic sequence from farthest southeast (sta. 1) to farthest northwest (sta. 18). Means with component data hidden represent coincident shallow and deep values.

1992) observed that, although time of arrival of the first fish (TFAP) was strongly related to estimated fish densities, the maximum number of fish seen at a station (MAXNO) either was unrelated or inversely related to densities. Our observation that MAXNO was highly correlated with an abundance estimate (CPUE) may at first seem contradictory to these prior findings. However, there are important differences between our methods and those of previous studies: previous deep-sea work operated in unproductive depths >2,000 m and cameras recorded data for at least 11 hours per station, whereas our study was limited to productive depths ≤100 m for which a relatively short soak time (10 min) was sufficient. In the deep-sea studies, all bait was open to consumption. The partly internal bait of our system created a reservoir of odor that persisted for the soak duration in most cases; puffers removed all bait in only 3 out of 75 deployments. Differences in rates of bait consumption between the two deep-sea stations and resulting variations in bait attractiveness may have contributed to the disparity between MAXNO and fish density in the deep-sea studies.

The MAXNO and TFAP indices in our study were highly correlated (Table 2). This correlation suggests that the greater the density, the faster the fish arrive at the bait. These data agree with the observations of Priede et al. (1990), where fish arrived at the camera faster at the station with presumed higher densities. Since the MAXNO and TFAP indices were both significantly correlated with CPUE in our study (Table 2), the MAXNO index was chosen as the best index of abundance because it had the better correlation. A persistent bait source and short soak time may have contributed to this stronger correlation. In the future, the use of MAXNO as an index of abundance should be reevaluated separately for each species and application.

Conclusions

Video cameras provide an accurate tool for sampling juvenile opakapaka, and the video MAXNO variable provides a relatively precise and accurate index of abundance. Based on 1993 data for a series of two camera deployments per station, minima of 17 to 22 pairs of deployments (34–44 sets) per study area would be necessary to detect a twofold change in juvenile opakapaka numbers (at α_2=0.1, 0.05, respectively). This could be accomplished within practical time limits (3–5 days) by using a large research vessel with two auxiliary small craft. If specimens are not needed—e.g. for age-growth studies—the video assembly described seems to be an ideal sampling technique for obtaining an index of abundance for comparisons between different areas or between different times, or between both. Additionally, video cameras can provide important, new information on habitat and behavior of juvenile opakapaka and associated species, an important aspect of our continuing research.

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