Age Estimation and Composition of Pelagic Armorhead *Pseudopentaceros wheeleri* from the Hancock Seamounts

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The pelagic armorhead *Pseudopentaceros wheeleri* is widely distributed in the North Pacific, but rarely collected until fishermen from the Soviet Union discovered large concentrations on the central North Pacific seamounts in the late 1960s (Sakiura 1972). The Soviet Union started a trawl fishery at the southern Emperor–northern Hawaiian Ridge (SE–NHR) seamounts (29°N, 179°E to 35°N, 171°E) in 1967, and the Japanese entered the fishery in 1969 (Sasaki 1986). Since then, intensive fishing occurred at the Northwest and Southeast Hancock Seamounts, the southeast limit of the pelagic armorhead seamounts. During the 1970s, the pelagic armorhead catch rate by Japanese fishing vessels at the Hancock Seamounts declined dramatically (Uchida and Tagami 1984). Commercial fishing at the Hancock Seamounts ceased in 1984, and finally, a 6-year fishing moratorium went into effect in August 1986 (NMFS 1986).

Pelagic armorhead have an unusual life history. At SE–NHR seamounts, adults spawn during December–March, as indicated by ovarian studies (Sasaki 1974, Bilim et al. 1978) and the occurrence of larvae and young juveniles in February and March (Borets 1980). As juveniles, they apparently are pelagic and occur to the north and northeast of the seamounts as far as the Alaskan gyre before returning to the seamounts (Fujii 1986, Boehlert and Sasaki 1988). At the SE–NHR seamounts, most of the pelagic armorhead caught in the fishery are 26–33 cm fork length (FL), although 15–40 cm FL specimens occur (Humphreys and Tagami 1986). Larger specimens (>40 cm FL), but none 26–33 cm FL, have been caught on the northern Hawaiian Ridge, from Kure Atoll to French Frigate Shoals (Tagami and Humphreys, in prep.).

Pelagic armorhead at the seamounts exhibit three morphological types: fat, intermediate, and lean (Humphreys et al. 1984, 1989; Humphreys and Tagami 1986). During their pelagic phase and when they recruit to seamounts, they are "fat" and their gonads are in an early stage of development. When gonads begin developing and spawning occurs, they transform from an "intermediate" to a "lean" stage. It has not been determined whether the lean fish recover to spawn again.

In this study, we determined which hard part is the most suitable for estimating armorhead age and determined the temporal meaning of perceived daily growth increments and apparent annual check marks on the sagitta, the preferred hard part. Chikuni (1970) and Vasil'kov and Borets (1975) used annuli on scales to estimate age, but their estimates did not agree. Furthermore, neither study used validation procedures, nor did they document the area of collection. The criteria we developed were used to estimate the age composition of pelagic armorhead captured on Southeast Hancock Seamount.

Methods and materials

Specimen collection

Pelagic armorhead were obtained at the Hancock Seamounts in 1976–85 from the Japanese trawler *Kitakami Maru*, and by bottom trawl and handline from the NOAA ship *Townsend Cromwell*. Random samples were obtained by pooling specimens from bucket scoops (range 2–100 kg/haul) on the *Kitakami Maru*, during 1 August–15 October 1981, and from a single haul on the *Townsend Cromwell* on 24 July 1984. Fish were measured for FL to the nearest millimeter and sexed by gonadal examination. Fish were classified, on the basis of color and body depth, to one of three body types: fat, intermediate, or lean (Humphreys et al. 1984). We also included a few very large specimens caught by handline on the northern Hawaiian Ridge seamounts between Kure Atoll and French Frigate Shoals and postlarvae caught in a surface tow with a Tucker trawl at Southeast Hancock Seamount, 23–24 February 1985. All postlarval specimens were preserved and stored in 70% ethanol.

Hard-part selection and check-mark counts

To determine which hard part was most suitable for estimating age, 13 structures (Table 1) were dissected from 5 specimens collected at the Hancock Seamounts. The structures were prepared for examination following modified procedures of Six and Horton (1977). The hypural

Manuscript accepted 25 July 1989.
Fishery Bulletin, U.S. 88:217–222.

Table 1
Comparison of check marks on various hard parts of five *Pseudopentaceros wheeleri* from the Hancock Seamounts.

	No. check marks by fish identification number				
Hard part	343	350	338	385	383
Sagitta	3	3	—	3	2
Centrum (vertebra)	3	3	3	3	2
Dorsal spine	3	3	3	3	2
Dorsal ray	0	0	0	0	0
Anal spine	3	0	3	3	2
Anal ray	0	0	0	0	0
Pelvic spine	0	0	3	3	0
Pelvic ray	0	0	0	0	0
Pectoral spine	0	0	0	0	0
Pectoral ray	0	0	0	0	0
Hypural	3	3	3	3	2
Maxillary	0	0	3	3	2
Scales	0	—	—	—	0

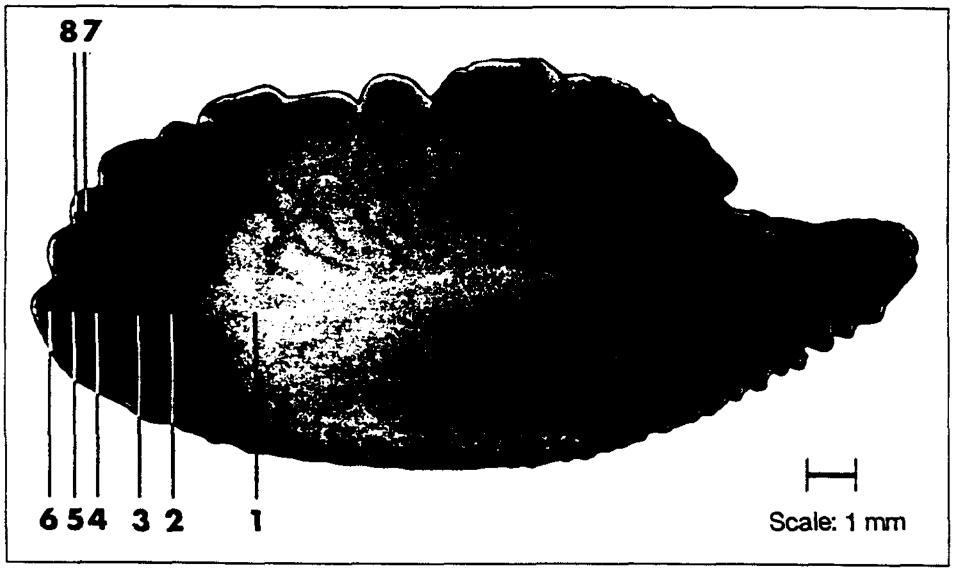

Figure 1
Sagitta of *Pseudopentaceros wheeleri* with annuli marked and numbered.

plate, maxillary, and vertebrae were cleaned of tissue and dried. Spines and rays of the dorsal, pelvic, pectoral, and anal fins were cleaned of tissue, embedded in resin, cross-sectioned in a continuous series from the base, and examined under a compound microscope. Both surfaces of a section were examined. Tissues were also examined under a dissecting microscope with reflected and transmitted light.

Sagittae were sanded lightly on the surfaces with no. 400 grit carborundum sandpaper, then, with a dissecting microscope, were examined whole against a black background while submerged in water. Check marks appeared as pairs of bright (opaque) and dark (translucent) concentric bands under reflected light (Fig. 1).

Scales were taken from nine different areas of the body. Three sites were along the lateral line: below the first dorsal spine, midway along the lateral line, and below the posterior end of the dorsal fin. Three sites were midway between the lateral line sites and the dorsal fin, and three were midway between the lateral line sites and the ventral border. Scales were taken from 20 fish of three different body types and from 13 fish, caught in February 1985, with three check marks on their sagittae. After being cleaned, scales were mounted in Euparal under a cover glass on a glass slide or flattened between two glass slides after being air dried.

Selection of the hard part for ageing was based on the consistency of perceived annual check mark counts and ease of preparation (Table 1). Only the sagittae, vertebral centrum, hypural plate, and dorsal and anal fin spines showed check marks. Counts of check marks from each part were identical (Table 1), indicating these structures could be used for estimating age if their check marks could be verified as annuli. The number of check marks on vertebral centrum, hypural plate, and maxillary was reduced by half upon drying. Soft rays of dorsal, pelvic, pectoral, and anal fins showed no marks that could be interpreted as check marks. Scales were without check marks, and their circuli appeared evenly spaced. Of all the structures compared, the sagitta was considered the best structure for estimating the age of pelagic armorhead.

Counts of daily growth increments

Sagittae removed at sea were stored in fresh water in vials and refrigerated; those not extracted at sea were frozen within the head and later removed in the laboratory. Sagittae were sanded lightly on both sides with no. 400 carborundum sandpaper until translucent and etched in a very dilute solution of HCl for 3–5 minutes. The acid was diluted until only 1–2 bubbles per second were formed in reaction to the calcium carbonate of the sagitta. This process was repeated until the increments became visible from the core to the tip of the postrostrum. The sagittae of postlarval specimens were teased from the skull, cleaned, and mounted in Euparal without further processing. To support the coverslip, each sagitta was mounted on a microscope slide in Euparal by using short segments of monofilament line slightly greater in diameter than the thickness of the otolith. Sagittae were examined under a compound microscope at 300× magnification.

Increment counts often took a circuitous route between the core and the tip of the postrostrum; the mean of 10 counts was used as the age estimate. Increment counts were routine for sagittae with two check marks but were more difficult for those with three check marks. Increment width in translucent zones decreased with increasing number of check marks (8.3 μm during year 1, 1.7 μm during year 2, and 1.5 μm during year 3), and incremental pattern was more variable after year 2.

Age estimation

Check marks could not be validated as annuli by conventional means (Beamish and McFarlane 1983). Mean increment counts were used to estimate the hatching time, assuming the first increment formed at or soon after hatching. This technique, though low in accuracy, may suffice when direct validation is unattainable (Gjøsaeter et al. 1984). To verify check marks as annuli, mean counts of growth increments for fish caught in February were then compared with counts of check marks, which were multiplied by 365.

Age composition of catches of pelagic armorhead at Southeast Hancock Seamount was based on checkmark counts (i.e., perceived annuli). Mean FLs between age-sex groups were compared using the Mann-Whitney paired test, since unequal variances occurred in one sample. To increase sample size of age-sex groups from the *Kitakami Maru* catch, randomly sampled specimens from Northwest and Southeast Hancock Seamounts were combined.

Results and discussion

Increment counts from demersal and oceanic adults and juvenile pelagic armorhead suggested that increments were deposited daily (Tables 2 and 3). A total of 88% of the estimated hatching dates of adults occurred within the spawning period, and the other three hatching dates were reasonably close to the spawning period.

Check marks appeared to be valid annuli based on number of daily growth increments for fish caught in February (Table 2). Sagittae with two check marks had approximately 730 increments (range 728–773, $N=5$), and those with three check marks had about 1095 increments (range 1037–1128, $N=4$). Check marks were also verified as annuli by a second but less precise method (Pannella 1971). Partial counts of 365 apparent daily growth increments appeared to coincide closely with the first pair of opaque and translucent zones of sagittae of age-1 and -2 fish. Partial counts of about 730 apparent daily growth increments corresponded with the outer margin of the second translucent zone on sagittae of age-2 fish.

Fish caught in summer appeared to have completed check marks on their sagittae. Sagittae from fish caught in July with two check marks had increment

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Table 2
Age estimates of pelagic armorhead *Pseudopentaceros wheeleri* by counting apparent daily growth increments (GI) on sagittae.

Date captured	Fork length (mm)	Sex	Mean GI count	SD	Estimated hatching date	No. check marks	Body type
29 Oct. 1976	277[a]	M	623	25.63	8 Feb. 1975	2	—
18 June 1983	340	F	902	13.04	29 Dec. 1980	3	Fat
12 July 1984	300	F	576	24.03	13 Dec. 1982	2	Lean
12 July 1984	322	F	621	21.67	30 Oct. 1982	2	Intermediate
13 July 1984	305	M	549	43.83	10 Jan. 1983	2	Intermediate
13 July 1984	308	F	937	58.00	18 Dec. 1981	3	Lean
24 July 1984	309	M	907	94.29	28 Jan. 1982	3	Fat
24 July 1984	310	M	544	37.28	26 Jan. 1983	2	Fat
24 July 1984	322	M	923	92.46	13 Jan. 1982	3	Fat
24 July 1984	329	F	605	37.94	26 Nov. 1982	2	Fat
25 July 1984	307	F	586	37.16	16 Dec. 1983	2	Intermediate
25 July 1984	319	F	914	39.99	22 Jan. 1982	3	Intermediate
29 July 1984	303	M	853	51.39	28 Mar. 1982	3	Intermediate
16 Feb. 1985	282	M	728	46.10	18 Feb. 1983	2	Lean
16 Feb. 1985	290	M	1037	26.80	15 Apr. 1982	3	Lean
16 Feb. 1985	293	M	762	50.96	15 Jan. 1983	2	Fat
16 Feb. 1985	304	F	758	40.53	19 Jan. 1983	2	Lean
16 Feb. 1985	311	F	761	45.73	16 Jan. 1983	2	Lean
16 Feb. 1985	317	M	773	27.29	4 Jan. 1983	2	Lean
16 Feb. 1985	319	F	1128	79.66	14 Jan. 1982	3	Lean
16 Feb. 1985	320	F	1101	84.65	10 Feb. 1982	3	Lean
23 Feb. 1985	355	F	1065	51.32	25 Mar. 1982	3	Fat
25 July 1984	322[b]	M	951	69.04	16 Dec. 1981	3	Fat
25 July 1984	305[c]	—[d]	599	35.83	3 Dec. 1982	2	Fat
25 July 1984	310[e]	F	580	52.73	22 Dec. 1982	2	Fat

[a] Estimated from standard length.
[b] *Oshoru Maru*, lat. 45°26'N, long. 154°58'W.
[c] *Oshoru Maru*, lat. 45°26'N, long. 155°00'W.
[d] Gonad undeveloped.
[e] *Oshoru Maru*, lat. 45°26'N, long. 155°00'W.

Table 3
Age estimates of postlarval *Pseudopentaceros wheeleri*, determined by counts of apparent daily growth increments (GI) on sagittae.

Fork length (mm)	Capture date	Mean GI count	SD	Estimated hatching date
12.1	24 Feb. 1985	36.5	1.72	19 Jan. 1985
12.1	24 Feb. 1985	34.7	1.89	20 Jan. 1985
13.4	24 Feb. 1985	39.6	2.41	15 Jan. 1985
13.6	23 Feb. 1985	42.1	2.02	12 Jan. 1985
13.6	24 Feb. 1985	41.9	2.64	12 Jan. 1985
15.9	23 Feb. 1985	41.9	2.28	12 Jan. 1985
15.9	23 Feb. 1985	48.0	5.16	6 Jan. 1985
18.2	23 Feb. 1985	57.7	5.93	27 Dec. 1984

counts (544–621) roughly equivalent to 1.5 years, and those with three check marks had increment counts (853–937) roughly equivalent to 2.5 years (Table 2). In July, sagittae of age-1 and -2 fish appeared to have two and three translucent zones, respectively. The outer translucent zone probably was due to thinness at the edge of the sagittae. Another possibility is that the opaque zone formed over a short period (<2 months) and formed internally in the translucent zone so that the outer edge was opaque for only a brief period. This has also been observed for *Ammodytes tobianus* (Reay 1972). Regardless, the result would be an overestimation of age for part of the year if fish were sampled prior to the spawning season.

Table 4
Mean fork lengths (FL) of pelagic armorhead *Pseudopentaceros wheeleri* age groups at the Southeast Hancock Seamount.

		Male FL (mm)				Female FL (mm)			
Sample date	Age	Range	Mean	SD	*N*	Range	Mean	SD	*N*
Aug.–Oct. 1981	1.5	267–320	294	14.07	37	285–325	307	9.54	68
	2.5	304–304	304		2	283–329	310	14.08	8
July 1984	1.5	247–330	301	15.57	37	295–331	308	8.22	39
	2.5	285–326	307	13.96	13	290–342	315	10.89	27

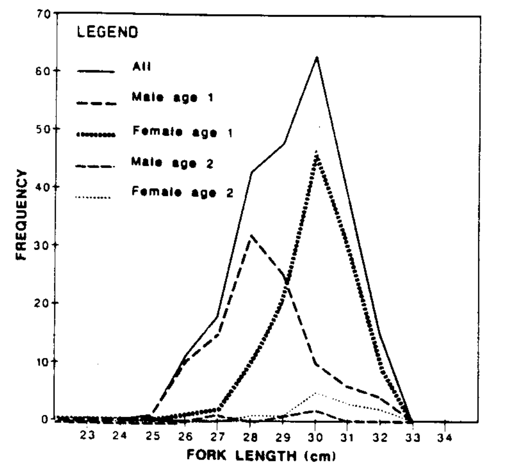

Figure 2
Length-frequency distribution of *Pseudopentaceros wheeleri* sampled at the Hancock Seamounts, 1 August–15 October 1981.

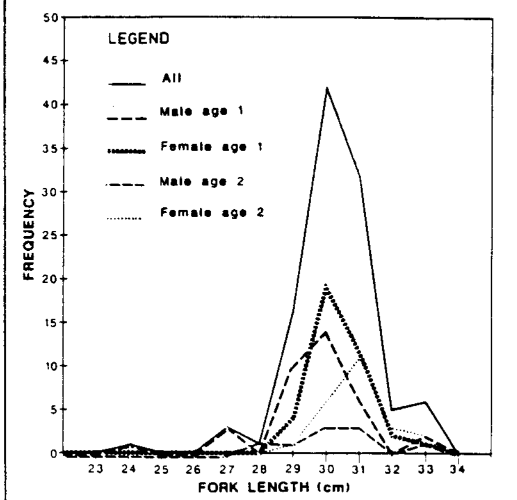

Figure 3
Length-frequency distribution of *Pseudopentaceros wheeleri* sampled at the Southeast Hancock Seamount, 24 July 1984.

We could not determine when the opaque zone formed because specimens were not obtainable throughout the year and the edge always appeared translucent.

Pelagic armorhead from the summer trawl fishery at the Southeast Hancock Seamount consisted of fish approximately ages 1.5 and 2.5, and yearlings were dominant in both 1981 (96%) and 1984 (66%) (Table 4). Yearling females appeared to be larger than males in both 1981 and 1984 samples (Figs. 2 and 3; Table 4). Differences between male and female mean lengths were significant in 1981 ($P<0.001$) and in 1984 ($P=0.025$), but difference in mean lengths for year-2 females and males in 1984 was not significant ($P=0.107$). The latter could have been due to small sample size; hence, larger samples should be examined before requiring separate growth curves for males and females. Our samples were not perfectly suited for group comparison because sex and age were unknown when the random samples were taken. Thus, unequal group size and unequal variances occurred. Due to our small sample size, slight skewness and kurtosis were encountered in comparing central tendencies of some age-sex groups. However, only the unequal variance between groups was serious enough to have affected the analyses.

Pelagic armorhead may attain sexual maturity before they reach the seamount. We base this on the age-length relationships of the three oceanic specimens (Table 2). After pelagic armorhead settle on the seamount, it appears that little growth occurs. Length-frequency distribution reported by other investigators (Sasaki 1986, Wetherall and Yong 1986) tends to confirm this observation. The lack of older (>age 3) individuals on the seamounts suggests that pelagic armorhead may spawn only one or two seasons and then die. Indeed, the presence of emaciated individuals suggests some postspawning mortality (Humphreys et al. 1984, Humphreys and Tagami 1986). Conversely, the existence of larger and older specimens in the northwestern Hawaiian Islands would suggest that longer life is possible and different life histories occur in different environments. Of the sagittae from large pelagic armorhead examined for comparison purposes, fish 43–48 cm FL ($N = 3$) had four check marks, fish 48–54 cm FL ($N = 2$) had five check marks, and the largest fish, 54.7 cm FL, had eight-plus check marks (Fig. 1). Although the relationship of these large pelagic armorhead to those on the seamounts is unknown, it is plausible that during the pelagic stage juveniles were displaced to the east, entered the subtropical gyre, and grew larger while spending 1–3 years longer in the open ocean before settling in the northern Hawaiian Ridge seamounts, southeast of the SE–NHR seamounts (Boehlert and Sasaki 1988).

Acknowledgments

We thank G. Kobayashi of the *Oshoru Maru* for collecting the oceanic pelagic armorhead specimens. B. Mundy verified the postlarval specimens. We also thank G.W. Boehlert, G.M. Cailliet, R.D. Methot, D.A. Somerton, and especially the anonymous reviewers for critically reviewing this manuscript.

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