Abstract.–Recruitment of individuals from the epipelagic phase to the demersal armorhead *Pseudopentaceros wheeleri* population at Southeast (SE) Hancock Seamount has typically been recognized by the influx of fish with a high fatness index (FI; body depth relative to fork length). Reliance on this index was dictated by the peculiarity of the seamount life history stage in which armorhead cease somatic growth soon after recruitment to the seamount and FI declines during seamount residence until death. Limited sampling opportunities and variability in FI at the time of recruitment preclude the exclusive use of FI as a means of identifying newly arrived recruits among recruits-of-the-year and hence the timing of annual recruitment. Settlement and recruitment to the seamount population are synonymous. Efforts to develop a method of identifying new recruits were initiated by an examination of epipelagic and seamount (SE Hancock) armorhead for differences in macroparasites as well as hepatosomatic and visceral fat-somatic indices. Of the two condition indices, the hepatosomatic index held the most potential but was considered too labile because prerecruits probably experience decreases that vary according to energetic demands during seamount migration. The monogenean gill parasite *Microcotyle macropharynx* was highly prevalent among seamount individuals in all sampling periods but absent from epipelagics. Based on probable rapid infection and maturation, identification of new recruits was based on the absence of mature *M. macrophaynx*. Results indicate that significant new recruitment occurred only during the late spring to midsummer sampling periods, and the mean FI of new seamount recruits was lower than that of comparable size epipelagics.

Use of a monogenean gill parasite and feasibility of condition indices for identifying new recruits to a seamount population of armorhead *Pseudopentaceros wheeleri* (Pentacerotidae)

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The armorhead *Pseudopentaceros wheeleri* (Hardy) in the North Pacific Ocean initially occupies an epipelagic and then demersal habitat during its life history. Progeny originate from winter spawning of the demersal armorhead population associated with the summit and upper slopes of the southern Emperor-northern Hawaiian Ridge (SE-NHR) seamounts (Fig. 1) (Bilim et al., 1978; Borets, 1979). Larvae are initially found in surface waters around the seamounts (Fedosova and Komrakov, 1975; Borets, 1979) but soon move or are advected into subarctic waters of the central and northeastern Pacific (Boehlert and Sasaki, 1988). Here they feed in oceanic surface waters and undergo somatic growth, accumulate energy reserves, but experience no reproductive development. These epipelagic individuals appear

deep-bodied and display a striking pattern of blue and silver blotches along their dorsal and lateral regions. The process and timing by which epipelagic individuals recruit back to the SE-NHR seamounts is not well understood (Boehlert and Sasaki, 1988). Individuals are primarily 28–33 cm fork length (FL) upon recruitment to the SE-NHR seamounts (Humphreys et al., 1989). Since recruits are similar in length and co-occur among the resident seamount population, settlement and recruitment to the seamounts are considered synonymous events (Humphreys et al., 1989). Unlike the epipelagics, the seamount population is demersal and virtually uniform in length, but morphologically variable. Three morphological variants (the "fat," "intermediate," and "lean" morphotypes) were previously recognized and found

to represent different stages of the demersal seamount phase (Humphreys et al., 1989). This variation intergrades from the deep-bodied, overall bluish-gray coloration of presumably recent recruits (fat morphotype) through progressively leaner forms of uniformly brownish coloration (intermediate and lean morphotypes). Relative body depth refers to the ratio of body depth at first anal spine to FL and hereafter is called the fatness index (FI; Somerton and Kikkawa, 1992). Usage of FI values recognizes that these variations form a continuum rather than discrete changes and has replaced classification by morphotype (Somerton and Kikkawa, 1992). Declining FI reflects the transformation by individuals as the elapsed time of seamount residence increases. During this phase, somatic growth ceases upon recruitment, and stored energy reserves are eventually mobilized for reproductive development and spawning. These processes contribute to the decline in FI and ultimately lead to death (Humphreys et al., 1989).

The discovery of large aggregations of armorhead over the summits and upper slopes of SE-NHR seamounts (Fig. 1) during exploratory work by the former Soviet Union in 1967–1969 (Komrakov, 1970) led to a full-scale bottom trawl fishery in this region by both Japanese and the former Soviet trawl fleet (Uchida and Tagami, 1984). By the end of 1975, the cumulative combined fleet catch of armorhead was some 880,000 metric tons (t). Total annual catch of armorhead by the Japanese trawl fleet declined dramatically after 1976 (Humphreys et al., 1984) and continues to remain low throughout the SE-NHR region (R. Humphreys, unpubl. data). In 1977 the Hancock Seamounts, located in the southermost portion of the SE-NHR trawl fishery, came under U.S. jurisdiction with the implementation of the 200-mile fishery conservation zone (Humphreys et al., 1984). During 1978–1984, several Japanese trawlers were allowed to fish the Hancock Seamounts but were regulated by permit and an annual catch quota (Uchida and Tagami, 1984;
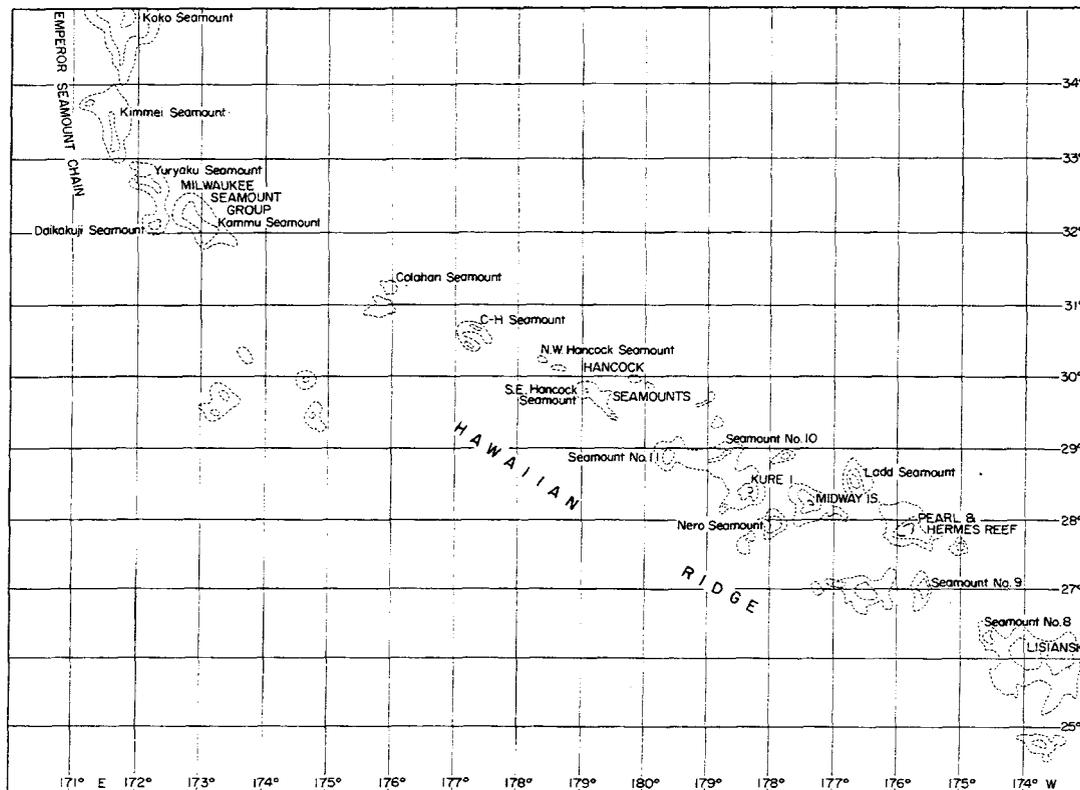

Figure 1
The major habitat of dermersal armorhead is located over the southern Emperor-northern Hawaiian Ridge (SE-NHR) seamounts extending from Koko Seamount to the northwest down through the Hancock Seamounts in the southeast region.

Somerton and Kikkawa, 1992). Owing to sustained low annual catches at the Hancock Seamounts, the National Marine Fisheries Service (NMFS) Honolulu Laboratory implemented both a research stock assessment program in 1985 and recommended institution of a moratorium (in effect since 1986) prohibiting trawl fishing at the Hancock Seamounts (Somerton and Kikkawa, 1992). The remainder of the SE-NHR seamounts, which represent some 90% of the historical trawl fishery in terms of habitat and overall catch, lie in international waters and under no fishery management control. As increases in armorhead biomass at Hancock and other SE-NHR seamounts appear to depend exclusively on recruitment, recent work has focused on examining the temporal pattern of seamount recruitment and the biological characteristics of new recruits. Boehlert and Sasaki (1988) used monthly length-weight data recorded by the Japanese at four SE-NHR seamounts during May 1972–December 1973 to estimate the seasonality of recruitment. Assuming that new recruits have a condition factor of ≥2.0, they found recruitment highest during April–May 1973 and secondary peaks in August 1972 and July 1973. Annual recruitment to Southeast (SE) Hancock Seamount, one of two guyots composing the Hancock Seamounts, was sporadic between 1978 to 1990. Strong recruitment (≥50% of population biomass) at SE Hancock Seamount occurred only in 1980 and 1986, and moderate recruitment (ca. 20–30% of population biomass) in 1988 and 1990, based on catch per unit of effort (CPUE) and FI distributions derived from Japanese trawl data and NMFS stock assessment surveys (Somerton and Kikkawa, 1992).

Little further progress, however, has been made in discerning the timing of recruitment and biological characteristics of newly arrived recruits. The apparent temporal variability in recruitment, the change in FI during time elapsed between recruitment and sampling, coupled with limited sampling opportunities, make the identification and study of new recruits and their temporal recruitment pattern problematic. A potential alternative for identifying newly recruited armorhead uses biological indicators to distinguish a new seamount arrival from longer resident armorhead. Parasites have been frequently used as biological indicators in fish and their benefit to studies of fish stock separation, movement, and diet are numerous (Williams et al., 1992). In relation to seamount studies, differences in the trematode parasite fauna of sablefish off Canada's west coast led Kabata et al. (1988) to surmise that seamount populations of sablefish are distinct and separate from those sablefish inhabiting the continental slope. Since seamount armorhead populations are derived from epipelagic individuals, we examined specimens of both life history phases for parasite differences and other distinguishing features. We report on the feasibility of using a monogenean gill parasite and two condition indices as potential indicators of new seamount recruits.

Methods

Epipelagic specimens of *P. wheeleri* ($n = 53$) were incidentally captured from the central North Pacific (around lat. 45°N, long. 155°W) in July 1984 and 1985 and from the eastern North Pacific (around lat. 46°N, long. 129°W) in July 1985 by the Japanese fishing vessels *Oshoro Maru* and *Tomi Maru No. 88*, respectively, during salmon longline and surface drift gillnet operations. These specimens were saved intact and stored frozen prior to examination. Specimens of seamount armorhead ($n = 1,220$) were collected from the southern end of the SE-NHR at SE Hancock Seamount (29°48′N, 179°04′E; see Fig. 1) by bottom longline gear during research cruises of the NOAA ship *Townsend Cromwell* in June 1985, August and October 1986, April and August 1987, and January, July, August, and November 1988. All seamount specimens were derived from efforts beginning in 1985 to estimate armorhead relative abundance (catch per unit of effort) at SE Hancock Seamount by using standardized assessment techniques described in Somerton and Kikkawa (1992). Seamount specimens were either saved intact and stored frozen, or gills and viscera were removed and preserved at sea in either alcohol-formalin-acetic acid (AFA) solution or placed in a dilute (0.0004%) formalin solution for several hours and then preserved in 10% formalin. Collection data for armorhead specimens included body weight, FL, body depth at first anal spine, sex, and date and location of capture. Measurements were made to the nearest millimeter, and body weight to nearest gram.

Under a dissecting microscope, the gill arches and visceral organs of armorhead specimens were examined for macroparasites. Guidelines proposed by Sindermann (1983) were followed to determine which species have potential as biological tags. Ideal parasite characteristics include ease of detection and identification, a single host-life cycle, and temporal stability in prevalence. Furthermore, the parasite should persist in the host during the study, and prevalence should differ significantly between study areas. These criteria were best fulfilled by the monogenean *Microcotyle macropharynx* (Mamaev), based on examinations of the seven parasite taxa (monogenean *Trochopus* sp., digenean *Bivesicula* sp., larvae of the nematode *Anisakis* type I, nematode *Hysterothylacium*

sp., an unidentified caligoid copepod, and juveniles of an unidentified gnathiid isopod) found in the epipelagic and seamount armorhead collected in June 1985 and August 1986. Subsequent examinations of armorhead were restricted to the gills where *M. macropharynx* were exclusively found. Specimens of *M. macropharynx* were readily distinguished from *Trochopus* sp. by the disk-shaped opisthaptor of the latter monogenean. All specimens of *M. macropharynx* were initially identified as that of *M. sebastis* though the pharynx of these specimens appeared to be unusually large[1]. During the review process, a new species description (Mamaev, 1989) of the monogenean *M. macropharynx* collected in 1969–70 from *P. richardsoni* (=*P. wheeleri*) in the Hawaiian Islands region was brought to the attention of the senior author. Subsequently specimens initially identified as *M. sebastis* were re-examined and all found to be *M. macropharynx*[2]. The large pharynx (in relation to the anterior suckers) of *M. macropharynx* distinguishes this species from all other species of *Micocotyle* (Mamaev, 1989). Each *M. macropharynx* was staged as either immature or potentially mature, based on absence or development of the paired yolk ducts, respectively. These organs are the last to develop before egg development in the related species *M. sebastis* (Thoney, 1986). All parasite taxa were saved and stored in 70% ethyl alcohol. Prevalence and mean intensity of *M. macropharynx* in seamount armorhead were computed for each sampling period. Following the terminology defined in Margolis et al. (1982), prevalence (expressed as a percentage) refers to the number of host species infected with a particular parasite species, divided by the number of hosts examined; and mean intensity is derived by dividing the total number of a particular parasite species by the number of individual hosts infected by that parasite. Prevalence and mean intensity data from seamount armorhead were partitioned into two FI groups of <0.26 and ≥0.26. This grouping is based on the observation that 0.26 was the lowest FI found for epipelagic armorhead in this study and thus a possible minimum FI for newly arrived seamount recruits.

Liver and visceral fat weights were also determined for the 27 epipelagic armorhead >27.5 cm FL (of comparable length to seamount individuals) and 410 seamount armorhead collected during October 1986 (*n* = 115) and January (*n* = 195), July (*n* = 18), and November 1988 (*n* = 82). Liver and visceral fat deposits were

[1]R. R. Payne, Department of Biological Sciences, Biola Univ., La Mirada, CA, personal commun. 1988.

[2]R. R. Payne, Department of Biological Sciences, Biola University, La Mirada, CA, pers. commun. 1992.

removed from the body cavity, blotted dry, and weighed to the nearest 0.1 g. Liver and visceral fat weights are expressed in relation to total body weight and referred to as the hepatosomatic index (HSI) and visceral fatsomatic index (VFSI), respectively. Data was arcsine transformed and tested for normality with the Lilliefor's method of the Kolmogorov-Smirnov test (Wilkinson, 1990). Sample means were compared by either *t*-test, or by Mann-Whitney test if samples remained nonnormal (Wilkinson, 1990).

Estimates of the proportion of recruits-of-the-year to the total SE Hancock armorhead population during each sampling period were based on stock-assesssment-derived FI distributions of the armorhead population. That proportion of the FI distribution ≥0.26 were considered recruits-of-the-year. Data and procedures used to calculate the population FI distribution are presented in Somerton and Kikkawa (1992). The proportion of recruit-of-the-year armorhead in each sampling period un-infected by mature stages of *M. macropharynx* was estimated from results of the prevalence data for those armorhead (from samples examined for *M. macropharynx*) with a FI ≥0.26.

Results

Microcotyle macropharynx were not present in any of the 53 epipelagic armorhead examined but were present in all 775 seamount armorhead with FI <0.26 and in 417 (93.7%) of 445 specimens with FI ≥0.26. Among seamount armorhead with FI <0.26, both the combined (irrespective of maturity stage) category and the immature and mature stage of *M. macropharynx* were highly prevalent (>75%) in all nine sample periods surveyed (Table 1). A similar pattern of high *M. macropharynx* prevalence was found among the seamount armorhead with FI ≥0.26 although instances of lower prevalence appear during the two earliest sample periods (Table 1). Mean intensity of immature *M. macropharynx* in both FI groups was considerably lower in each sample period than the corresponding mean intensities of the mature stage and combined category (Table 2). Mean intensity of mature stage *M. macropharynx* in each sample period and FI group was sufficiently high to ensure easy detection in armorhead infected with mature stage individuals of this monogenean. A wide range in sizes of *M. macropharynx*, including mature stages with eggs, was present among the gills of armorhead, indicating that this parasite has a monoxenous life cycle.

Seamount armorhead without mature *M. macropharynx* represented 5.2% (64) of the 1,220 fish examined. Among those seamount armorhead found un-

Table 1

Prevalence of the monogenean *Microcotyle macropharynx* in the gills of armorhead *Pseudopentaceros wheeleri* by fatness index (FI) groups of <0.26 and ≥0.26, collected from Southeast Hancock Seamount during 1985–88. Within each FI group, prevalence is further categorized by maturity stage of monogenean or regardless of (combined). Prevalence expressed as a percentage of total number (n) of armorhead examined. Differences in (n) between maturity stages indicates missing data. Occurrences of combined (n) exceeding (n) of both maturity stages represents instances where monogeneans from an additional sample were not staged.

Sample period	FI <0.26			FI ≥0.26		
	Immature stage	Mature stage	Combined	Immature stage	Mature stage	Combined
Jun 1985	98.0	95.9	100.0	70.0	45.0	80.0
	n=49	n=49	n=50	n=20	n=20	n=20
Aug 1986	93.0	100.0	100.0	68.8	66.7	75.0
	n=57	n=57	n=58	n=48	n=48	n=48
Oct 1986	92.5	100.0	100.0	84.9	96.2	99.1
	n=80	n=80	n=80	n=106	n=106	n=107
Apr 1987	80.6	100.0	100.0	85.2	96.3	96.3
	n=134	n=137	n=137	n=27	n=27	n=27
Aug 1987	88.2	100.0	100.0	95.8	89.6	95.8
	n=68	n=68	n=68	n=48	n=48	n=48
Jan 1988	94.5	100.0	100.0	100.0	100.0	100.0
	n=181	n=183	n=183	n=12	n=12	n=12
Jul 1988	93.3	100.0	100.0	78.8	80.8	90.4
	n=45	n=45	n=45	n=52	n=52	n=52
Aug 1988	93.6	100.0	100.0	90.4	78.8	94.2
	n=47	n=47	n=47	n=52	n=52	n=52
Oct–Nov 1988	96.6	97.7	100.0	98.7	97.5	100.0
	n=87	n=87	n=87	n=79	n=79	n=79

Table 2

Mean intensity of the monogenean *Microcotyle macropharynx* in the gills of armorhead *Pseudopentaceros wheeleri* by fatness index (FI) groups of <0.26 and ≥0.26, collected from Southeast Hancock Seamount during 1985–88. Within each FI group, mean intensity is further categorized by maturity stage of monogenean or regardless of (combined). Sample size from which mean intensity is based on is denoted by (n). Differences in (n) between maturity stages indicates missing data. Occurrences of combined (n) exceeding (n) of both maturity stages represents instances where monogenean was present but stage of maturity not determined. Smaller sizes of (n) in this table compared to the (n) of corresponding cells in Table 1 indicates instances where data on prevalence, but not mean intensity, is available.
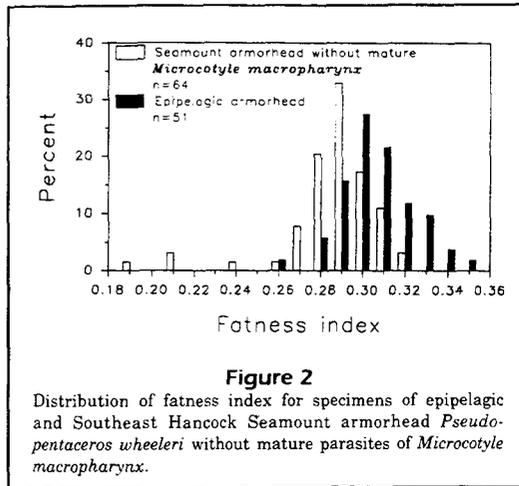
Sample period	FI <0.26			FI ≥0.26		
	Immature stage	Mature stage	Combined	Immature stage	Mature stage	Combined
June 1985	12.23	35.72	52.06	4.64	95.22	57.63
	n=48	n=47	n=50	n=14	n=9	n=16
Aug 1986	9.09	63.84	72.12	6.91	30.41	34.03
	n=53	n=57	n=58	n=33	n=32	n=36
Oct 1986	9.74	88.01	97.03	5.42	65.77	68.18
	n=74	n=80	n=80	n=90	n=102	n=106
Apr 1987	16.21	65.17	79.92	19.23	162.86	181.14
	n=79	n=24	n=24	n=13	n=14	n=14
Aug 1987	17.97	58.48	75.48	14.42	58.21	72.68
	n=31	n=33	n=33	n=19	n=19	n=19
Jan 1988	15.84	56.66	71.11	20.44	110.00	130.44
	n=31	n=35	n=35	n=9	n=9	n=9
Jul 1988	14.47	27.69	41.25	7.67	36.47	37.80
	n=30	n=32	n=32	n=18	n=17	n=20

infected by mature stage *M. macropharynx*, virtually all were of a FI ≥0.26 (Table 3). The four armorhead with FI <0.26 and un-infected by mature *M. macropharynx* had FI values disjunct from similarly un-infected armorhead with FI ≥0.26 (Fig. 2). Mean FI's of the seamount armorhead group (FI ≥0.26) without mature *M. macropharynx* (x = 0.291) and the epipelagic group (x = 0.307) were significantly different (t-test, P < 0.001). From samples of seamount armorhead (FI ≥0.26) examined for prevalence of mature stage *M. macropharynx*, the percentage of those found without mature *M. macropharynx* was higher in the June–August samples (Table 3). However, these latter results did not always correspond with peaks in the proportion of the seamount armorhead population (with FI ≥0.26) obtained from stock assess-
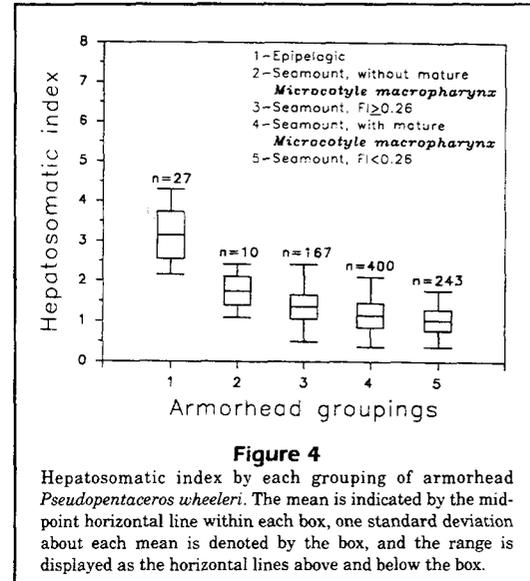
Table 3

Percent absence of mature stages of the monogenean *Microcotyle macropharynx* from the gills of armorhead *Pseudopentaceros wheeleri* by fatness index (FI) groups of <0.26 and ≥0.26, sampled from Southeast Hancock Seamount during 1985–88. Sample size examined for each category denoted by (n).

Sample period	FI <0.26	FI ≥0.26
Jun 1985	4.1	55.0
	n=49	n=20
Aug 1986	0	33.3
	n=57	n=48
Oct 1986	0	3.8
	n=80	n=106
Apr 1987	0	3.7
	n=137	n=27
Aug 1987	0	10.4
	n=68	n=48
Jan 1988	0	0
	n=183	n=12
Jul 1988	0	19.2
	n=45	n=52
Aug 1988	0	21.2
	n=47	n=52
Nov 1988	2.3	2.5
	n=87	n=79

Figure 2
Distribution of fatness index for specimens of epipelagic and Southeast Hancock Seamount armorhead *Pseudopentaceros wheeleri* without mature parasites of *Microcotyle macropharynx*.

Figure 4
Hepatosomatic index by each grouping of armorhead *Pseudopentaceros wheeleri*. The mean is indicated by the midpoint horizontal line within each box, one standard deviation about each mean is denoted by the box, and the range is displayed as the horizontal lines above and below the box.

ment surveys (Fig. 3; data taken Somerton and Kikkawa (1992) from FI distributions for each sample period except November 1988).

Mean HSI ($x = 3.147$; Fig. 4) of the epipelagic group was significantly different from that of seamount armorhead with FI ≥ 0.26 ($x = 1.358$, Mann-Whitney test, $P < 0.001$) and those with FI <0.26 ($x = 1.028$, t-test, $P < 0.001$). Furthermore, none of the seamount armorhead except for two individuals in the FI ≥ 0.26 group had HSI values exceeding the lowest value (2.154) of the epipelagic group. Differences between the mean HSI of the two seamount FI groups were
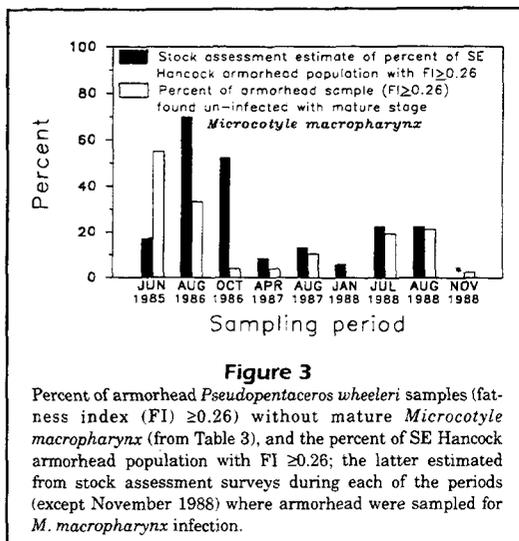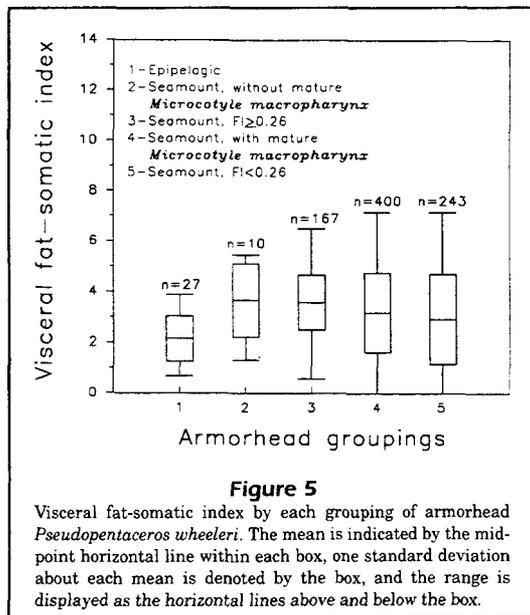

Figure 3
Percent of armorhead *Pseudopentaceros wheeleri* samples (fatness index (FI) ≥ 0.26) without mature *Microcotyle macropharynx* (from Table 3), and the percent of SE Hancock armorhead population with FI ≥ 0.26; the latter estimated from stock assessment surveys during each of the periods (except November 1988) where armorhead were sampled for *M. macropharynx* infection.

also highly significant (Mann-Whitney test, $P < 0.001$). Regardless of FI value, the difference in mean HSI between epipelagics and seamount armorhead without ($x = 1.744$, t-test, $P < 0.001$) and with ($x = 1.148$, t-test, $P < 0.001$) mature *M. macropharynx* remained significantly different, as were differences between the latter two groups (t-test, $P < 0.001$). The seamount armorhead group without mature *M. macropharynx* exhibited the least overlap in HSI values with other seamount groups (Fig. 4).

For the epipelagic group, mean VFSI ($x = 2.152$; Fig. 5) was significantly different from seamount armorhead with FI ≥ 0.26 ($x = 3.580$, t-test, $P < 0.001$) and those with FI <0.26 ($x = 2.933$, Mann-Whitney test, $P = 0.007$). Mean VFSI differences between the latter two seamount groups were also significant (Mann-Whitney test, $P < 0.001$). The mean VFSI of the epipelagic group was also significantly different from that of seamount armorhead with ($x = 3.185$, Mann-Whitney test, $P < 0.001$) and without ($x = 3.663$, t-test, $P = 0.009$) mature *M. macropharynx*, whereas the latter two seamount groups did not significantly differ in mean VFSI (Mann-Whitney, $P = 0.364$). Overlap in VFSI among the various groups (Fig. 5) was substantially greater than exhibited for HSI.

Discussion

The complete absence of the monogenean *M. macropharynx* from all epipelagic armorhead exam-

Figure 5
Visceral fat-somatic index by each grouping of armorhead *Pseudopentaceros wheeleri*. The mean is indicated by the midpoint horizontal line within each box, one standard deviation about each mean is denoted by the box, and the range is displayed as the horizontal lines above and below the box.

ined, and its high prevalence among seamount armorhead during all sample periods, support the notion that infestation of this parasite originates at the seamount. The prevalence of immature *M. macropharynx*, particularly for those armorhead with FI <0.26, indicates that infestation at the seamount is probably a continuing process. The presence of *M. macropharynx* in all 775 seamount armorhead with FI of <0.26 also negates the likelihood of a sizable proportion of seamount armorhead becoming uninfested over time.

The maturation rate of *M. macropharynx* on armorhead remains undetermined, but Thoney (1986) has found the oncomiracidia of the morphologically similar *M. sebastis* capable of maturing within 12 days on the gills of black rockfish *Sebastes melanops* (Girard) off northern California. Although armorhead are different hosts, inhabit greater depths, and are geographically distant from black rockfish, the temperature range (12°–17°C) used by Thoney (1986) to determine the maturation time of *M. sebastis* is similar to that found on the summit and upper slope of SE Hancock Seamount. Assuming this rapid maturation also occurs among *M. macropharynx* infecting armorhead, we propose that armorhead with exclusively immature *M. macropharyx* have probably only recently become infested and have seamount residence times that differ little from those of uninfested armorhead. The 0.26 FI value may represent a lower FI limit for potential new recruits, for only 6% of seamount armorhead without

mature *M. macropharynx* had FI values <0.26 and the lowest FI value of the epipelagics examined was 0.26. However, an unknown proportion of armorhead with FI ≥0.26 perhaps recruit during the previous year at sufficiently high FI values that these FI values still remain above 0.26 when sampled the following year. Even in this situation, such individuals would be infected with mature *M. macropharynx* by the time they are sampled the following year and therefore not mistaken for new recruits. The presence of *M. macropharynx* probably cannot identify recruits that arrived one or several months before sampling if initial infection occurs soon after recruitment and *M. macropharynx* mature some two weeks thereafter. Hence, our technique can detect only new recruits among the recruit-of-the-year population and is therefore limited to determining whether recruitment is a continuous process.

Of the two condition indices, VFSI shows little promise as an indicator of new recruits, for the VFSI values in epipelagic and seamount individuals broadly overlap, regardless of FI and the presence or absence of mature *M. macropharynx*. Conversely, virtually no overlap in HSI values occurs between epipelagic individuals and any of the seamount armorhead groupings. Preliminary results of sagittal otolith increment enumeration on epipelagic individuals (>27.5 cm FL) and SE Hancock armorhead without mature *M. macropharynx* indicates a common age around 2.5 years (R. Humphreys, unpubl. data). This appears to suggest that those epipelagic individuals examined either remain pelagic or represent "strays" who will eventually or have begun a delayed movement that will result in recruitment to a SE-NHR seamount but a protracted epipelagic phase. The higher mean HSI value of these epipelagics versus seamount armorhead (FI ≥0.26) un-infected by mature *M. macropharynx* suggests that HSI decreases somewhere during the period between movement to the seamounts and time of capture after seamount recruitment. To explain the higher mean HSI of epipelagics and evaluate its efficacy as a recruitment indicator, this forementioned period must be examined in relation to both time and distance.

Of the 27 epipelagic individuals with FLs comparable to seamount populations (>27.5 cm FL) and least distant from the SE-NHR seamounts, 22 were collected around lat. 45°N, long. 155°W; some 2,860 km northeast of the SE-NHR seamounts. Summertime captures of smaller (22–26 cm FL) epipelagics are also frequent from the above general location and indicate an age of some 1.5 years (Boehlert and Sasaki, 1988; R. Humphreys, unpubl. data). Since recruit-of-the-year seamount armorhead are age 2.5 years (R. Humphreys, unpubl. data), these smaller individuals apparently represent the year class which recruit to the SE-NHR

seamounts in the following year. Allowing a one-year period (recruitment by the following summer) for individuals of the 1+ epipelagic year-class to move from the open ocean site (45°N 155°W) to the SE-NHR seamounts and also that the total distance traversed is twice the straight-line distance between these sites (assuming this is comparable to results of open-sea tracking of coho salmon *Oncorhynchus kisutch* reported in Ogura and Ishida (1992)), a rough estimate of the average ground speed required is 18 cm/s if currents are disregarded. Based on a length (27.1 cm FL) midway between the average FL of 1+ ($x = 24.49$ cm FL) and 2+ year-old ($x = 29.64$ cm FL) epipelagic specimens collected during summers at the open ocean site, individuals would need to swim 0.66 body length/s to arrive at an SE-NHR seamount one year later. This speed is close to the mean sustained cruising speeds (0.2–0.5 body length/second) typical of horizontally migrating fish (Beamish, 1978). Since no evidence exists of gonadal maturation in the epipelagic stage (Humphreys et al., 1989), the major energy demand during seamount migration is likely locomotion, in addition to basal metabolism. It is unknown whether feeding occurs during this migration; however, McKeown (1984) suggests that even if fish species feed during migration, the added energy intake may be negated by the additional energy required for feeding activity. Regardless of feeding, lipid reserves are typically used during migration (McKeown, 1984), and their storage in the liver and muscle makes these prime sites from which energy reserves can be drawn (Woodhead, 1975). As such, the liver is susceptible to net decreases in weight by the end of migration; an example of this occurs among migrating Barents Sea cod *Gadus morhua* (Woodhead, 1975). Evidence of fewer prey contents among higher FI armorhead examined at SE Hancock[3] indicates that recent recruits initially may feed little at the seamounts. This suggests that the liver remains susceptible to continued energy depletion and therefore continued decrease in liver weight. Assuming that liver weight is declining relatively faster than body weight, the HSI will not only decrease by the time of initial recruitment to the seamount but perhaps also during the interval between initial recruitment and sampling. Therefore, an annual or seasonal change in mean HSI among new recruits may be caused by inter- or intra-annual differences experienced by epipelagics in terms of environmental conditions and distance traversed during the seamount migration, along with an unknown time gap between initial recruitment and sampling. Hence, using HSI as a recruitment indicator appears to be inherently more labile and thereby less feasible and reliable than the method based on the absence of mature *M. macropharynx*.

The parasite approach revealed that new recruitment coincided primarily with the late spring and midsummer sampling periods. Somerton and Kikkawa (1992) have analyzed the recruitment patterns of armorhead to SE Hancock, using the modal progression of FI in which separate modes are considered annual cohorts. If a modal influx of high FI fish represents a "recruitment cohort," estimated recruitment was highest in terms of biomass (58 t) and percentage (79%) of the SE Hancock population during August and October 1986, whereas the next highest recruitment (8 t and 21% of the population, respectively) in July and August 1988 was comparatively modest. Interestingly, however, the level of new recruitment, as determined by the percentage of sampled armorhead (FI ≥0.26) un-infected with mature *M. macropharynx*, was highest in June 1985 and very low in October 1986. These results appear contrary to stock assessment based estimates of modest and high proportions of recruit-of-the-year armorhead (FI ≥0.26) in the seamount population during June 1985 and October 1986, respectively (see Fig. 2). These results can be reconciled if we consider that the rate of post-recruitment decline in FI (estimated at 0.00169/month; Somerton and Kikkawa (1992)) does not allow one to decipher between recruits which may have just arrived and those which arrived months prior to sampling. The absence of mature stage *M. macropharynx* appears to be the only criteria examined in this study capable of detecting whether a recruit-of-the-year (FI ≥0.26) is a new arrival to the seamount. Based on this criteria, the level of new recruitment during the months sampled was highest in June, less so in July and August, and very low during October, November, January, and April. These results tend to corroborate evidence of similar seasonal armorhead recruitment at other SE-NHR seamounts (Boehlert and Sasaki, 1988).

Recruits identified via the parasite approach typically have FI values ≥0.26 ($x = 0.291$). However, a high FI value alone provides no assurance that an individual is a new recruit. The difference in mean FI between epipelagic individuals and new recruits (un-infected with mature *M. macropharynx*) may indicate that FI decreases sometime before epipelagics of recruitment size reach the seamounts. This can be adequately examined only after both groups are further sampled.

Acknowledgments

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Literature cited

Beamish, F. W. H.
 1978. Swimming capacity. *In* W. S. Hoar and D. J. Randall (eds.), Fish physiology, vol. VII (Locomotion), p. 101–187. Academic Press, New York.
Bilim, L. A., L. A. Borets, and L. K. Platosina.
 1978. Characteristics of ovogenesis and spawning of the boarfish in the region of the Hawaiian Islands. *In* Fisheries oceanography, hydrobiology, biology of fishes and other denizens of the Pacific Ocean, p. 51–57. Izv. Pac. Ocean Sci. Res. Inst. Fish. Oceanogr. (TINRO), Vladivostok, 102. (Engl. transl. by W. G. Van Campen, 1986, 9p., Transl. No. 106; available Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396.)
Boehlert, G. W., and T. Sasaki.
 1988. Pelagic biogeography of the armorhead, *Pseudopentaceros wheeleri*, and recruitment to isolated seamounts in the North Pacific Ocean. Fish. Bull. 86:453–465.
Borets, L. A.
 1979. The population structure of the boarfish, *Pentaceros richardsoni*, from the Emperor Seamounts and the Hawaiian Ridge. J. Ichthyol. 19:15–20.
Fedosova, R. A. and O. E. Komrakov.
 1975. Feeding of *Pentaceros richardsoni* frys in the Hawaiian region. [In Russ.] Invest. Biol. Fishes Fish. Oceanogr., TINRO, Vladivostok 6:52–55. (Engl. transl. by W. G. Van Campen, 1985, 4 p., Transl. No. 100; available Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396.)
Humphreys, R. L. Jr., D. T. Tagami, and M. P. Seki.
 1984. Seamount fishery resources within the southern Emperor-northern Hawaiian Ridge area. *In* R. W. Grigg and K. T. Tanoue (eds.), Proceedings of the Symposium on Resource Investigations in the Northwestern Hawaiian Islands, Vol. 1, May 25–27, 1983, University of Hawaii, Honolulu, HI, p. 283–327. UNIHI-SEAGRANT-MR-84-01.
Humphreys, R. L. Jr., G. Winans, and D. T. Tagami.
 1989. Synonymy and life history of the North Pacific pelagic armorhead, *Pseudopentaceros wheeleri* Hardy (Pisces: Pentacerotidae). Copeia 1:142–153.

Kabata, Z., G. A. McFarlane, and D. J. Whitaker.
 1988. Trematoda of sablefish, *Anoplopoma fimbria* (Pallas, 1811), as possible biological tags for stock identification. Can. J. Zool. 66(1): 195–200.
Komrakov, O. E.
 1970. Distribution and fishery of the boarfish (*Pentaceros richardsoni* Smith) in the Hawaiian region. In the collection: The present state of biological productivity and the volume of biological resources of the world ocean and prospects for their utilization, p. 155–163. Kaliningrad. (Engl. transl. by W. G. Van Campen, 1987, 9 p., Transl. No. 117; available Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396.)
Mamaev, Yu. L.
 1989. On species composition and morphological features of the *Microcotyle* genus (Microcotylidae, Monogenoidea). [In Russ.] Investigations in Parasitology, Collection of Papers, p. 32–38.
Margolis, L., G. W. Esch, J. C. Holmes, A. M. Kuris, and G. A. Schad.
 1982. The use of ecological terms in parasitology (report of an ad hoc committee of the American Society of Parasitologists). J. Parasitol. 68:131–133.
McKeown, B. A.
 1984. Fish migration, Chapter 4 (Bioenergetics). Croom Helm, London.
Ogura, M., and Y. Ishida.
 1992. Swimming behavior of coho salmon, *Oncorhynchus kisutch*, in the open sea as determined by ultrasonic telemetry. Can. J. Fish. Aquat. Sci. 49:453–457.
Sindermann, C. J.
 1983. Parasites as natural tags for marine fish: a review. Northwest Atl. Fish. Organ. Sci. Counc. Stud. 6:63–71.
Somerton, D. A., and B. S. Kikkawa.
 1992. Population dynamics of pelagic armorhead *Pseudopentaceros wheeleri* on the Hancock Seamounts. Fish. Bull. 90:756–769.
Thoney, D. A.
 1986. Post-larval growth of *Microcotyle sebastis* (Platyhelminthes: Monogenea), a gill parasite of the black rockfish. Trans. Am. Microsc. Soc. 105:170–181.
Uchida, R. N., and D. T. Tagami.
 1984. Groundfish fisheries and research in the vicinity of seamounts in the North Pacific Ocean. Mar. Fish. Rev. 46(2):1–17.
Wilkinson, L.
 1990. SYSTAT: The system for statistics. Evanston, IL. SYSTAT, Inc. (Version 5.01).
Williams, H. H., K. MacKenzie, and A. M. McCarthy.
 1992. Parasites as biological indicators of the population biology, migrations, diet, and phylogenetics of fish. Reviews in Fish Biology and Fisheries, 2:144–176.
Woodhead, A. D.
 1975. Endocrine physiology of fish migration. Oceanogr. Mar. Biol. Annua. Rev. 13:287–382.