gas-liquid chromatographic analysis (see footnote 4).

Acknowledgments

We thank the following laboratories for helping to establish the validity of these methods by participating in verification studies: Seattle, Detroit, and New Orleans District Laboratories of the U.S. Food and Drug Administration; the Gulf Breeze, Fla., Field Station of the Environmental Protection Agency; the Wisconsin Alumni Research Fund Institute, Madison, Wis.; and the Iowa Department of Agriculture, State Chemical Laboratory, Des Moines.

Robert Reinert willingly shared his methods with us before they were published. Daniel B. Menzel, formerly of the Institute of Marine Resources, University of California, Berkeley, Calif., generously shared his knowledge of the intricacies of chlorinated hydrocarbon analysis. Laura G. Lewis provided technical support in developing this procedure.

Literature Cited

HOROWITZ, W. (editor).
1970. Fat-containing foods. *In* Official methods of analysis of the Association of Official Analytical Chemists. 11th ed., p. 480. Assoc. Off. Anal. Chem., Wash., D.C.

PESTICIDE ANALYTICAL MANUAL.
1977. Gas-liquid chromatography. *In* Pesticide analytical manual, Vol. I, Chapter 3. U.S. Dep. Health, Educ., and Welfare, Food and Drug Admin., Wash., D.C.

PORTER, M. L., S. J. V. YOUNG, AND J. A. BURKE.
1970. A method for the analysis of fish, animal, and poultry tissue for chlorinated pesticide residues. J. Assoc. Off. Anal. Chem. 53:1300-1303.

REINERT, R. E.
1970. Pesticide concentrations in Great Lakes fish. Pestic. Monit. J. 3:233-240.

SNYDER, D., AND R. REINERT.
1971. Rapid separation of polychlorinated biphenyls from DDT and its analogues on silica gel. Bull. Environ. Contam. Toxicol. 6:385-390.

VIRGINIA F. STOUT

Northwest and Alaska Fisheries Center
National Marine Fisheries Service, NOAA
2725 Montlake Boulevard East
Seattle, WA 98112

F. LEE BEEZHOLD

Northwest and Alaska Fisheries Center
Present address: *Food Chemical and Research Laboratories, Inc.*
4900-9th N.W., Seattle, WA 98107

GROWTH OF JUVENILE SPOT PRAWN, *PANDALUS PLATYCEROS*, IN THE LABORATORY AND IN NET PENS USING DIFFERENT DIETS

Floating net pens have been used to culture Pacific salmon, genus *Oncorhynchus*, in the marine waters of the West Coast since 1969 (Mahnken 1975). Although it has been a monoculture effort to date, use of a companion crop species such as the spot prawn, *Pandalus platyceros* Brandt, could diversify and enhance this industry.

In 1975 the National Marine Fisheries Service selected the spot prawn to examine as a potential companion species to net pen-reared salmon. The spot prawn was selected as a candidate for several reasons: 1) it has a rapid growth rate and large size compared with other pandalids (Butler 1964); 2) it can be successfully cultured to maturity in captivity (Prentice 1975); 3) it will reproduce in captivity, often for two consecutive years (Rensel and Prentice 1977); 4) it is gregarious and is normally not cannibalistic; 5) it adapts to vertical or horizontal substrates; and 6) it scavenges for, and accepts, a wide variety of foods (Wickins 1972).

Coincident to investigating the prawn as a companion crop to salmon, several prawn diets were evaluated with prawns held in tanks and net pens at the NMFS Aquaculture Experiment Station on Puget Sound near Manchester, Wash. These experiments were conducted using diets made up of underutilized marine species or fishery byproducts that are available to most salmon farmers.

Materials and Methods

The spot prawns used in the experiments were laboratory-reared progeny of females captured in Hood Canal, Wash. Three concurrent experiments with juvenile prawns (<1 yr of age) began 10 July 1975 (Table 1).

Experiment A was conducted in the laboratory where prawns were held in flowing seawater tanks at 110 animals/m^2 of immersed substrate. Four diets were evaluated: 1) steamed mussel, *Mytilus edulis*, meat; 2) chopped salmon that had died in nearby net pens; 3) feces and pseudofeces from the Pacific oyster, *Crassostrea gigas* (eight oysters per replicate having a mean weight (total) of 153 g); and 4) no food (control). Diets 1 and 2 were fed every other day while diet 3 was always present in varying amounts. A sample of 10 prawns for each of four replicates was measured during each of

TABLE 1.—Growth and survival of juvenile *Pandalus platyceros* during three tests.

Experiment	Location	Diet	No. of replicates	Start of experiment: No. of prawns in each replicate	Start of experiment: Mean weight (g)	60 days after start of experiment: Mean survival (%)	60 days after start of experiment: Mean weight (g)	End of experiment: No. of days	End of experiment: Mean survival (%)	End of experiment: Mean weight (g)
A (prawns alone)	Laboratory tanks	Mussel	4	25	0.72	82	2.52	90	74	3.14
		Salmon	4	25	0.62	83	2.27	90	71	2.61
		Oyster wastes	4	25	0.69	64	1.06	(1)	(1)	(1)
		No food	4	25	0.64	26	1.07	(1)	(1)	(1)
B (prawns alone)	Net pens	Mussel	2	200	0.64	98	3.14	365	69	10.30
		Salmon[2]	2	200	0.63	98	2.79	365	64	10.61
C (prawns and salmon)	Net pens	Variety of feeds[3]	1	100	0.64	93	3.42	206	93	8.60

[1]Terminated at 60 days.
[2]Includes net-fouling organisms.
[3]Includes salmon mortalities, uneaten fish feed (Oregon moist pellets), salmon feces, and net-fouling organisms.

three 30-day sampling periods. Carapace lengths[1] and individual wet weights (nonblotted) were measured to the nearest 0.5 mm and 0.01 g, respectively. In all experiments growth data were analyzed by one-way analysis of variance and survival by chi-square tests.

In Experiment B, prawns were held in two net pens measuring 1.2 × 1.8 × 1.8 m and constructed of knotless nylon web (6.8-mm stretched measure mesh). Each pen was vertically divided into three equal compartments (6.5 m^2 of substrate each) with only the outer two being stocked with prawns. The prawns were stocked at a density of 30.8/m^2 of immersed substrate. The net pens were covered with black plastic to prevent bird predation and to reduce light intensity. Two dietary treatments were evaluated, mussel meat and salmon. Each treatment consisted of two replicates and was fed exclusively on one of the two diets. Feed was to excess every other day.

A sample of 50 prawns/replicate (100/treatment) was measured for length and weighed during each of eight sampling periods, except during the last three periods in which all survivors were measured and weighed. The prawns were sampled at the beginning of the experiment and 32, 60, 88, 146, 205, 292, and 365 days later.

In Experiment B, in addition to evaluating the diets, we studied the net cleaning ability of the prawns and the value of the organisms on the net (i.e., the net fouling organisms) as a supplementary food source. Samples of net fouling organisms were taken from inside and outside of a compartment containing prawns (test) and inside and outside of one not containing prawns (control). The nets were selected at random, and each sample consisted of all the organisms on the net within the area of two 20-cm-diameter circles; one circle was at 0.25-m depth, and the other was at 1.0-m depth. The material collected was identified, enumerated, and measured volumetrically. The nets were sampled during November 1975 and March 1976.

In Experiment C, juvenile prawns were stocked in a net pen with coho salmon, *Oncorhynchus kisutch*, (age-group 0) that averaged 20 g each. A single net pen (without dividers) having a substrate area of 10.8 m^2 was used. Prawn density was 9.3/m^2 of substrate, and salmon density was 82/m^3 of water. The salmon were fed Oregon moist pellets at 3% body weight/day; however, no feed was provided for the prawns other than what they could scavenge. All the prawns were measured at each of seven periods: at the beginning of the experiment and 15, 33, 60, 89, 146, and 206 days later.

Care was taken to standardize culture conditions such as lighting, substrate type, and water temperature within each experiment. This was not practical between experiments because of inherent differences between laboratory and net pen work.

Stocking density differed between experiments, but its impact on growth and survival (agnostic behavior and feeding dominance) was minimized by distributing an excess of food throughout the rearing enclosure. In several years of behavioral observations we have rarely seen overtly agressive or cannibalistic behavior in spot prawns.

Results and Discussion

Mussel-fed juvenile prawns had the best survival and growth rate of all the prawns raised in the laboratory tanks (Experiment A); 74% of the

[1]Carapace length is defined as the distance from the base of the eyestalk to the posterior middorsal edge of the carapace.

prawns survived, and they had a final mean weight of 3.14 g (Table 1). The prawns fed salmon were significantly smaller ($P<0.01$) than the mussel-fed group. However, the growth of prawns in both the mussel and salmon diet groups equaled or exceeded the growth reported for a natural population in British Columbia (Butler 1964).

Growth was similar between oyster waste and no food diet groups (Table 1), but survival was significantly different ($P<0.01$), 64% for oyster waste and 26% for no food supplement. Prawns fed oyster wastes or receiving no food grew at a slower rate than the prawns in the other two diet groups; this portion of the study was terminated after 60 days.

The poor growth of prawns fed oyster wastes contrasts with the good growth of lobster *Homarus americanus* fed algae and oyster wastes in a sewage enriched raceway system (Mitchell 1975). In that study intermediate organisms that fed on the solid wastes of oysters were also available as a food source for juvenile lobsters. In our study, raw unfiltered seawater was used, but cleaning the tanks twice weekly prohibited the establishment of intermediate organisms.

Prawns in the net pens (Experiment B) grew significantly faster than those in the laboratory (Experiment A) for both mussel- ($P<0.01$) and salmon-fed ($P>0.01$) treatments (Table 1). Further, there was no significant difference in the growth ($P>0.10$) or survival ($P>0.25$) of prawns fed mussel or salmon in the pens as there had been in the laboratory tanks.

In the net pens, the presence of net fouling organisms as an additional food source for the prawns could explain the improved growth over that seen with the same basic diets used in the laboratory. Net fouling organisms could have provided nutritional requirements that were deficient in the basic diets as provided in the laboratory.

Prawns in both diet groups were observed removing organisms that were on both the inside and outside surfaces of the net pens using their second periopods. The amount of net fouling organisms was reduced by the prawns in these en-

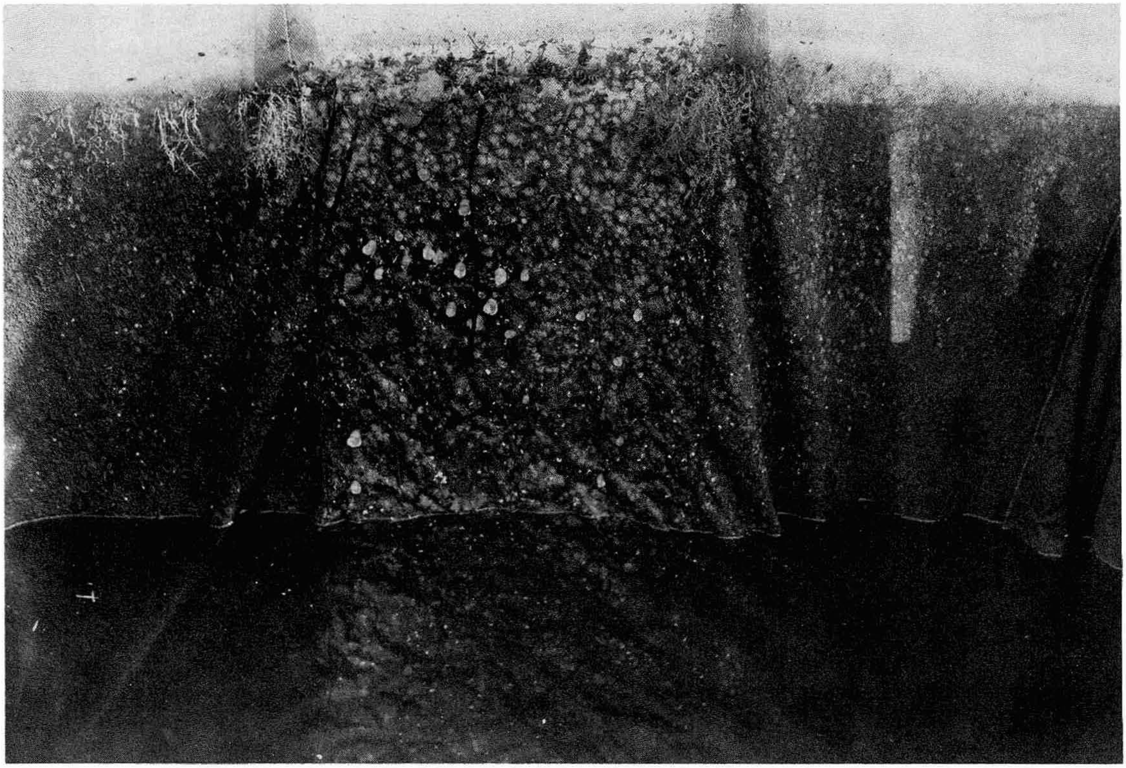

FIGURE 1.—Webbing of a three-chambered net pen showed reduced fouling in the right and left chambers (spot prawns present) compared with the center chamber without prawns.

closures (Figure 1, Table 2). The largest amount of organisms occurred at the shallower depths of the nets as in Moring and Moring's (1975) study of salmon net pens at the same site. Mussels, ascidians, and tubicolous polychaetes, *Spirorbis* sp., contributed the most fouling in the control chambers (without prawns). Except for a few *Spirorbis* sp., the net pen chambers with spot prawns were completely clean. Little algal growth was present due to the reduction of light by the black plastic covers.

Rearing prawns and salmon in the same net pen (Experiment C) proved encouraging. After 6½ mo of culture the growth of these prawns (Figure 2) exceeded that of the monoculture Experiment B ($P<0.01$) and that reported for a natural population (Butler 1964). Survival was 93% and not significantly different ($P>0.95$) from that of Experiment B.

There was no evidence of adverse salmon/prawn interaction. The types of food available to the prawns when reared with salmon included: dead fish, uneaten fishfood pellets, fish feces, and net-fouling organisms. The relative contribution of each was unknown.

A limiting factor to stocking juvenile prawns in commercial salmon net pens is the requirement that the prawns must be large enough to prevent them from going through meshes of the net. Smaller "nursery" nets of reduced mesh size could be hung inside the main salmon nets until the prawns reach a suitable size (about 4 g, or 3 mo of age).

Several advantages might accrue from using a scavenger, such as the spot prawn, as a companion crop in salmon culture. In Experiment B a reduction in net fouling was seen in net pens with prawns (Table 2, Figure 1). This reduction will aid salmon culture because it would allow greater water circulation within the enclosure, thus increasing dissolved oxygen levels and flushing of

TABLE 2.—Displacement volumes (milliliters) of fouling organisms on the inside and outside surfaces of net pens with and without *Pandalus platyceros* from July 1975 to March 1976. All pen chambers were clean at the start of the experiment. Sample area was 314.2 cm^2 of vertical mesh.

Location of sample	Depth of sample (m)	Net pen compartment with prawns		Net pen compartment without prawns	
		Nov. 1975	Mar. 1976	Nov. 1975	Mar. 1976
Inside of net	0.25	0.40	0.00	26.40	41.55
	1.00	0.00	0.00	10.50	12.03
Outside of net	0.25	0.25	0.50	9.00	17.00
	1.00	0.10	0.40	6.00	11.53

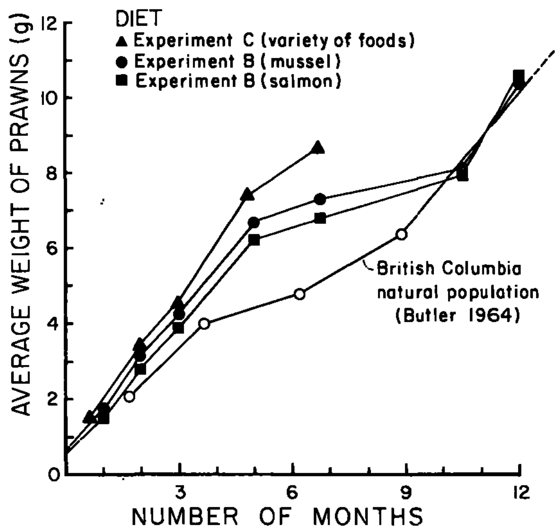

FIGURE 2.—Growth of juvenile *Pandalus platyceros* in net pens compared with a natural population.

metabolic wastes from the pens. A reduction in net maintenance cost might also be realized. Experiments B and C demonstrated that fish in the presence of net-fouling organisms was an acceptable food for the prawn (Figure 2); the utilization of dead salmon by a scavenger would be a valuable conversion of an otherwise unused protein and would reduce the labor needed to remove salmon mortalities from the system.

Further experiments are needed to determine proper stocking densities of prawns and salmon to maximize growth rates, survival, and to make optimum use of the net cleaning activities of the prawns. Further, while our studies showed that a single diet fed to prawns in the laboratory was not adequate for rapid growth, other studies (Kelly et al. 1976) have shown that combination raw diets could produce adequate growth. These combination diets need to be evaluated in the net pen system.

Literature Cited

BUTLER, T. H.
1964. Growth, reproduction, and distribution of pandalid shrimps in British Columbia. J. Fish. Res. Board Can. 21:1403-1452.

KELLY, R. O. A., A. W. HASELTINE, AND E. E. EBERT.
1976. Mariculture potential of the spot prawn, *Pandalus platyceros* Brandt. Aquaculture 10(1):1-16.

MAHNKEN, C. V. W.
1975. Status of commercial net pen farming of Pacific salmon in Puget Sound. *In* J. W. Avault, Jr., and R. Miller

(editors), Proc. 6th Annu. Meet. World Mariculture Soc., p. 285-298.

MITCHELL, J. R.
1975. A polyculture system for commercially important marine species with special reference to the lobster, *Homarus americanus*. *In* J. W. Avault, Jr., and R. Miller (editors), Proc. 6th Annu. Meet. World Mariculture Soc., p. 249-259.

MORING, J. R., AND K. A. MORING.
1975. Succession of net biofouling material and its role in the diet of pen-cultured chinook salmon. Prog. Fish-Cult. 37(1):27-30.

PRENTICE, E. F.
1975. Spot prawn culture: status and potential. *In* C. W. Nyegaard (editor), Proceedings of a seminar on shellfish farming in Puget Sound, Oct. 7, 1975, Poulsbo, Wash., p. 1-11. Wash. State Univ., Coll. Agric., Coop. Ext. Serv., Pullman.

RENSEL, J. E., AND E. F. PRENTICE.
1977. First record of a second mating and spawning of the spot prawn, *Pandalus platyceros*, in captivity. Fish. Bull., U.S. 75:648-649.

WICKINS, J. F.
1972. Experiments on the culture of the spot prawn *Pandalus platyceros* Brandt and the giant freshwater prawn *Macrobrachium rosenbergii* (de Man). Fish. Invest., Minist. Agric., Fish. Food (G.B.), Ser. II, 27(5), 23 p.

JOHN E. RENSEL

Squaxin Island Tribe
Route 1, Box 257
Shelton, WA 98584

EARL F. PRENTICE

Northwest and Alaska Fisheries Center
National Marine Fisheries Service, NOAA
2725 Montlake Boulevard East
Seattle, WA 98112

LARVAL LENGTH-WEIGHT RELATIONS FOR SEVEN SPECIES OF NORTHWEST ATLANTIC FISHES REARED IN THE LABORATORY

Growth is an important connecting link in the functional influence of biotic and abiotic factors on the dynamics of fish populations. Length-weight relations are used by fishery scientists to describe the growth characteristics of species or populations and as a basis of evaluating the consequences of environmental influences on growth. Length-weight relations are also used in assessing production when combined with age and growth information and in determining length or weight in a situation where either one or the other is unknown due to sampling procedures.

Studies of the early life of fishes are receiving increasing emphasis, particularly with regard to growth and survival in the larval stage. Survival during this period is thought to be minimal and potentially variable from year to year. Small changes of tenths of a percent in mortality have the potential to produce orders of magnitude differences in eventual adult populations. Larval growth can be influenced due to food limitations and varying abiotic factors (Houde 1974; Lasker 1975; Laurence 1977). Because of these facts, fishery scientists are particularly concerned with two aspects: 1) quantifying variable larval growth and survival, relating it to subsequent year-class recruitment, and applying it to traditional stock-recruitment relationships where recruitment has often been considered constant; and 2) the potential use of this type of information in evaluating the increasing effects of pollution or other environmental perturbations because of the fragility and sensitivity of larvae to changing or altered environmental variables.

Solutions to these problem areas require quantitative knowledge of growth parameters of larval fishes, and length-weight relations can be helpful in providing information or establishing relationships between pertinent sets of data. It is generally thought that weight[1] is a better measure of absolute growth of fish larvae than length as well as the prime determinant of condition when combined with length. Many species exhibit allometric or disproportionate length-weight growth. This is especially true during the period of metamorphosis when some species display varying or unusual body proportions with age (Blaxter 1969) and length does not increase in proportion to increasing weight. Additionally, recent attempts to construct models of larval survival, as influenced by environmental variables and density dependent feeding relationships, require weight determinations for estimates of biomass and caloric turnover between larval and prey trophic levels.

There is an extensive data base to asses larval fish growth and survival based on ichthyoplankton collected on survey cruises during the last 75 yr by marine laboratories throughout the world. Unfortunately, almost all of these data are in standard or total length measurements as they are much more easily and rapidly taken than dry weights. The difficulty involved in obtaining dry

[1]Weight for species in this research refers to dry weight. Dry weight is the most accurate for fish larvae because accurate wet weights are difficult to obtain and yield variable results on organisms as small as fish larvae.