(Equation (1)), then Equation (1) can be used to easily estimate the catch per trap day that would prevail at a standardized soak time. Comparing catch per trap day at a standardized soak time will provide a more accurate measurement of relative abundance. The relative fishing power of a trap as estimated by Equation (1) yields the same results as the computations of adjusted traps in Table 2, column 5.

Conclusions

When the soak time is variable in trap fisheries, trap days may not be an accurate index of fishing effort. Furthermore, there is evidence that as the exploitable stock declines the profit-maximizing soak time declines, which can result in a measured catch per trap day that will not reflect the declining relative abundance. It is possible to adjust trap days or catch per trap day according to the soak time to more accurately reflect fishing effort (catch per unit of effort). The calibration of this adjustment requires data on the relationship between the catch and soak time. It is recommended that in the future soak time be documented to facilitate this calibration.

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C. BRUCE AUSTIN

Department of Economics, School of Business and Division of Biology and Living Resources Rosenstiel School of Marine and Atmospheric Science University of Miami, FL 33149

SPECIES COMPOSITION AND RELATIVE ABUNDANCE OF LARVAL AND POST-LARVAL FISHES IN THE COLUMBIA RIVER ESTUARY, 1973

Few ichthyoplankton surveys of northern Pacific coast estuaries exist: Waldron (1972) and Blackburn (1973) surveyed larvae in northern Puget Sound; Eldridge and Bryan (1972) conducted a 1-yr survey in Humboldt Bay, Calif.; Pearcy and Myers (1974) conducted an 11-yr survey in Yaquina Bay, Oreg. No data on ichthyoplankton are available for the Columbia River estuary.

In 1973, the National Marine Fisheries Service conducted a survey of zooplankton in the Columbia River estuary to study productivity and seasonal variation of zooplankton populations. The survey also captured larval and post-larval fishes. This paper reports species composition, size range, and seasonal and horizontal occurrence of larval and post-larval fishes within the Columbia River estuary. Substrate was provided for egg deposition as an additional technique to determine if spawning was occurring in the estuary. Such investigations are valuable to assessing the importance of the estuary as a spawning and nursery ground.

Methods

Seven stations from the Columbia River's mouth to Tongue Point upstream 29 km were sampled once a month with a 0.5-m plankton net January to December 1973 (Figure 1). A single station was sampled monthly from March to

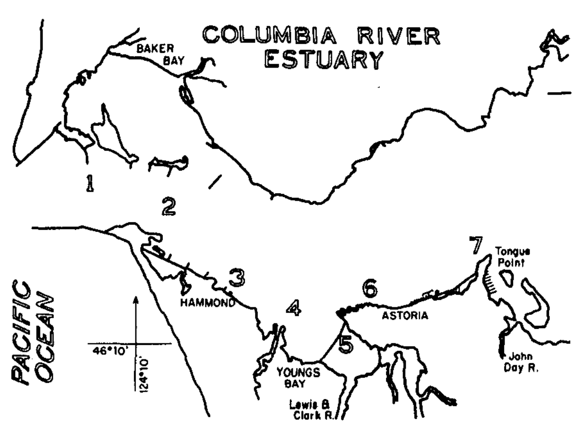

FIGURE 1.—Columbia River estuary, showing location of sampling stations.

December 1973 with a 0.9-m Isaacs-Kidd Midwater Trawl. Stations were located in channel areas where depths ranged from 12 to 26 m, with the exception of station 5 which had a maximum depth of 4.8 m.

A Coast Guard utility boat (12.3 m long) converted for research was used to sample stations during daylight at high tide. The 0.5-m net with 0.24-mm mesh was towed for 9 min at each station bottom to surface using a 3-stepped oblique tow (3 min at each level). Volume of water strained was estimated by a centrally located TSK[1] flowmeter. The 0.9-m trawl was towed once a month for 15 min at station 2 March through December 1973. The trawl was towed in a 3-stepped oblique manner (5 min at each level), surface to bottom.

Samples were preserved immediately on board the vessel with 10% Formalin in seawater. In the laboratory larvae were measured using a dissecting microscope having a micrometer eyepiece. Measurements refer to standard lengths measured from snout tip to notochord tip; after formation of the caudal fin, to the end of the hypural plate. Salinities and temperatures were recorded on the bottom and at the surface at each station with a Beckman model RS5-3 induction salinometer.

Evergreen boughs were provided as spawning substrate January through July. A small trap constructed of hardware cloth was attached to the boughs to capture and identify fishes depositing eggs. The device was operated with a hand winch mounted on a pier near station 3 and examined three times per week.

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Results and Discussion

Species Composition

Larvae, postlarvae, and juvenile fishes from 13 families were captured during this investigation

TABLE 1.—Checklist of larval, post-larval, and juvenile fishes captured with a 0.5-m plankton net and a 0.9-m Isaacs-Kidd Midwater Trawl during 1973.

Family, scientific, and common names	Station captured	Size range (mm)	Total number	Month collected
Clupeidae:				
Clupea harengus pallasi, Pacific herring	1, 2, 3, 4, 6	10-40	15	Mar., May, June
Alosa sapidissima, American shad	2	44	1	Aug.
Engraulidae:				
Engraulis mordax, northern anchovy	1, 2, 3	22-68	21	Jan., Mar., Oct., Nov.
Osmeridae:				
Spirinchus thaleichthys, longfin smelt	1, 2, 3, 4, 5, 6, 7	6-64	1,959	Jan., June, Oct.-Dec.
Thaleichthys pacificus, eulachon	1, 2, 3, 4, 5, 6, 7	5-8	558	Feb.-May
Allosmerus elongatus, whitebait smelt	1, 2, 3, 4	45-58	27	Oct.-Jan.
Hypomesus pretiosus, surf smelt	1, 2	36-53	27	Jan.-Mar.
Undetermined spp.	1	10-30	34	Dec.-Mar.
Gadidae:				
Microgadus proximus, Pacific tomcod	1, 2, 3	5-61	4	Mar., June, July
Stichaeidae:				
Lumpenus sagitta, snake prickleback	2, 4	13-16	5	Jan.-Feb.
Pholidae:				
Pholis ornata, saddleback gunnel	1	18-20	4	Mar.
Ammodytidae:				
Ammodytes hexapterus, Pacific sand lance	1, 2	10-16	12	Mar.-Apr.
Scorpaenidae:				
Sebastes melanops, black rockfish	3	55-67	3	July
Sebastes spp.	1, 3	5	3	Jan.
Hexagrammidae:				
Ophiodon elongatus, lingcod	2	9,12	2	Feb.-Mar.
Hexagragrammos sp.	1	6,10	2	Jan.-Feb.
Cottidae:				
Leptocottus armatus, Pacific staghorn sculpin	1, 2, 3, 6	6-13	6	Jan.-Mar., May-Sept.
Enophrys bison, buffalo sculpin	1	5, 8	2	Feb.
Cottus asper, prickly sculpin	1, 2, 3, 4, 5, 7	6-12	204	Apr.-June
Hemilepidotus spinosus, brown Irish lord	2	32	1	Mar.
Oligocottus maculosus, tidepool sculpin	1	4-8	2	Jan.
Undetermined spp.	1	6-15	3	Jan.-Feb., June
Agonidae:				
Stellerina xyosterna, pricklebreast poacher	4	7-9	3	Feb.-Apr.
Cyclopteridae:				
Liparis rutteri, ringtail snailfish	1	12-32	3	Jan., Mar.-Apr.
Liparis puchellus, showy snailfish	2	18	1	June
Undetermined spp.	1, 2	3	2	Jan.-Mar.
Pleuronectidae:				
Psettichthys melanostictus, sand sole	1	28-34	3	June
Parophrys vetulus, English sole	1, 2, 3, 4	4-21	22	Jan.-Apr., Dec.
Isopsetta isolepis, butter sole	1, 2, 3, 4	4-7	7	Jan.-Apr.

(Table 1). A total of 2,152 larvae and postlarvae were taken in 84 tows with the 0.5-m net and 784 postlarvae and juveniles were captured in 10 tows with the 0.9-m trawl.

Early stages of 22 species were taken with the 0.5-m net. The catch was dominated numerically by the Osmeridae which accounted for 89% of the total. *Spirinchus thaleichthys* were the most numerous—composing 67% of the total catch. *Thaleichthys pacificus* represented 19% of the total. *Cottus asper* made up 7% of the total and each of the remaining individual species accounted for less than 1%.

Twelve species were captured with the trawl at Station 2. *Spirinchus thaleichthys*, 22-64 mm, composed 92% of the catch. Post-larval *Hypomesus pretiosus*, *Allosmerus elongatus*, and juvenile *Engraulis mordax* represented the majority of the remaining total. The trawl captured three species not taken with the 0.5-m net: *Ophiodon elongatus*, *Hemilepidotus hemilepidotus*, and *Alosa sapidissima*.

Species composition of ichthyoplankton in the Columbia River estuary differed from that found in other northwest estuaries. Waldron (1972) and Blackburn (1973) found larval Gadidae dominated catches in Puget Sound. In Humboldt Bay, Eldridge and Bryan (1972) reported 82% of the total catch was *Clupea harengus pallasi* and *Lepidogobius lepidus*. In Yaquina Bay, Pearcy and Myers (1974) reported this combination of species was 90% of the catch. *Clupea h. pallasi* in the Columbia River estuary composed less than 1% of the total and no *L. lepidus* were captured.

Seasonal Abundance

Larval and post-larval fishes were most abundant January through May. During the summer no larval or post-larval stages were taken at any of the seven stations. Similar findings were reported in Humboldt Bay (Eldridge and Bryan 1972) and in Yaquina Bay (Pearcy and Myers 1974).

Abundance estimates are based on average monthly catches at all stations with the 0.5-m net (Figure 2). A peak of 1.1/m^3 occurred in March, primarily the result of an influx of newly hatched *Spirinchus thaleichthys*. A maximum average catch of 1.5/m^3 occurred in May, the result of an increased number of *Thaleichthys pacificus* and *Cottus asper*. Maximum catch during the year was 4.0/m^3 and occurred at station 2 in May. The

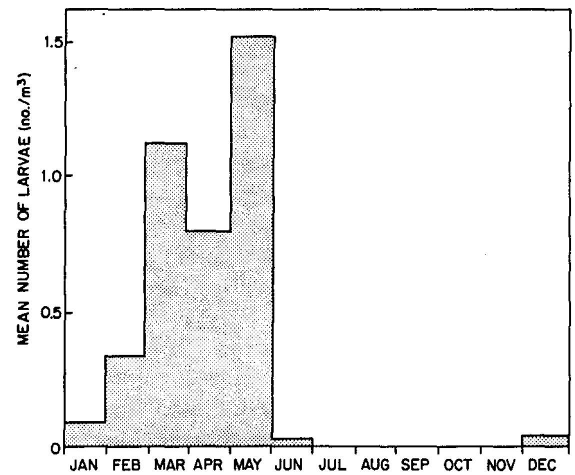

FIGURE 2.—Seasonal density of ichthyoplankton at seven locations in the Columbia River estuary during 1973. These results show average catch at seven stations with the 0.5-m plankton net.

composition was entirely *S. thaleichthys*, *T. pacificus*, and *C. asper*.

Juveniles were the only stage captured with the trawl from summer through fall. Those captured were: *Microgadus proximus* (60-61 mm), *Sebastes melanops* (55-67 mm), *Alosa sapidissima* (44 mm), *Leptocottus armatus* (11-13 mm), *Allosmerus elongatus* (49-58 mm), *Engraulis mordax* (45-68 mm), and *Spirinchus thaleichthys* (45-64 mm).

Horizontal Variation

The greatest variety of species was captured at stations nearer the mouth where salinities were higher. Large variations in tides and river flow combine to create a fluctuating horizontal saline intrusion; salinity is dissipated upstream and station 7, except during reduced river flow in the fall, is essentially fresh water (Haertel and Osterberg 1967 and Misitano 1974). The reduction in salinity upstream was reflected by a corresponding decrease in the variety of species (Figure 3). At station 1 there were 22 identifiable species and at stations 5 and 7 three species: *S. thaleichthys*, *T. pacificus*, and *C. asper*. Stations 5, 6, and 7, which exhibited similarly reduced salinities, accounted for 47.8% of the total larvae captured in the estuary with the 0.5-m net. This high percentage is due to the influx of the two species of osmerid larvae entering the estuary during the first part of the year.

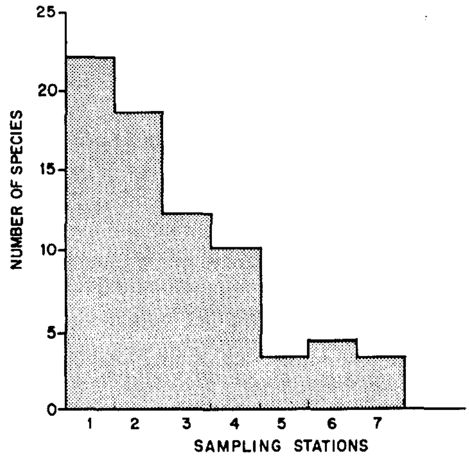

FIGURE 3.—Number of species of larval, post-larval, and juvenile fishes collected at each station in the Columbia River estuary during 1973.

Spawning on Provided Substrate

Evergreen boughs placed in the water attracted two species to deposit eggs, *Clupea harengus pallasi* and unidentified snailfish (Cyclopteridae). Thirty-three ripe adult *C. h. pallasi,* 163 mm average length, were trapped 10 April through 17 July confirming identification of the eggs. Light spawning was first observed on the boughs 10 April; moderate deposition 1-3 July. Ova were viable, eyed eggs were observed.

Adult snailfish began entering the trap 13 February. Eggs were deposited on boughs 12 and 26 February. Eggs were viable and emergent larvae were observed. Fifteen gravid adults were captured 13 February through 3 March. This snailfish has some characteristics in common with *Liparis rutteri,* which is also present in the estuary. The unknown snailfish has been closely examined and is now considered to be an undescribed species by Carl Bond at Oregon State University, Corvallis, Oreg.

Gravid adults of two species of Cottidae were captured by trapping. Ripe *Leptocottus armatus* were taken 18 February and 19 March but no spawning was observed. Jones (1962) found egg survival for this species optimum at 10-15% indicating a probably spawning population in the Columbia River estuary. Ripe *Cottus asper* were trapped 26 March, 4 and 9 April. This cottid's newly hatched larvae, as described by Stein (1972), was the third most abundant species in the estuarine ichthyoplankton. Krejsa (1967) noted that coastal populations of this cottid migrate downstream to spawn in brackish water. The capture of ripe adults and large numbers of newly hatched larvae verifies spawning of *C. asper* in the estuary.

Utilization of the Estuary

Data obtained from this investigation indicated four species, *Clupea harengus pallasi, Cottus asper, Leptocottus armatus,* and a new species of snailfish, utilized the Columbia River estuary for spawning in 1973. The greatest number of species was captured near the mouth suggesting most species are oceanic in origin.

Spirinchus thaleichthys, the most numerous species, was captured at all stations. This anadromous osmerid was reported by Hart (1973) to spawn in streams near the sea. The presence of newly hatched larvae, as described by Dryfoos (1965), confirms the presence of a spawning population in the lower Columbia system. The capture of early stages almost the year round indicates a major importance of the estuary to this species.

Thaleichthys pacificus is also an anadromous osmerid in the Columbia River. Some mainstream spawning occurs, but the majority of the run spawns in the Cowlitz River, a tributary 109 km upstream (Smith and Saalfeld 1955). Although large numbers of larvae were captured February to May, they were yolk bearing stages, 6-8 mm, indicating a downstream drift through the estuary to the ocean soon after hatching. Similar findings were reported by Larkin and Ricker (1964).

No evidence of estuarine spawning by pleuronectids was indicated. Although the upper estuary is a nursery for juvenile *Platichthys stellatus* (Haertel and Osterberg 1967), no larvae or postlarvae of this species were captured. Pearcy and Myers (1974) captured only three larvae in 11 yr in Yaquina Bay, indicating entry into the estuary is accomplished after metamorphosis. *Parophrys vetulus* were captured at two size ranges: 4-6 mm and 20-21 mm. Information from other estuaries (Pearcy and Myers 1974; Misitano 1976) indicates young *P. vetulus* enter estuarine nurseries after completion of metamorphosis.

Isopsetta isolepis utilizes the Columbia River estuary as a nursery. The National Marine Fisheries Service conducted a bottom trawling survey in the estuary from March 1973 to June 1974 (J. T. Durkin pers. commun.). *Parophrys* *vetulus,* 85-165 mm, and *I. isolepis,* 95-155 mm, were commonly captured. *Isopsetta isolepis,* 4-7 mm, were captured with 0.5-m plankton net. No later stages were taken. Richardson (1973) took this species (12-22 mm) off Oregon close to shore. Entry into the estuary probably occurs as metamorphosed juveniles.

Several types of sampling equipment should be utilized in future studies to capture early stages near bottom, on tide flats, in embayments, and during darkness. This preliminary investigation indicated little spawning occurred in this west coast estuary; most species captured were spawned in the ocean, or were anadromous species that spawned upstream and drifted into the estuary. Results of this investigation and bottom trawling by other researchers indicated this estuary is utilized primarily as a nursery grounds by the post-larval and juvenile stages of several species.

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DAVID A. MISITANO

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

A NOTE ON: "VELOCITY AND TRANSPORT OF THE ANTILLES CURRENT NORTHEAST OF THE BAHAMA ISLANDS"

Interest of fishery scientists in the Antilles Current east of the Bahama Islands stems from a generally accepted hypothesis that it served as a conveyor of larvae of large pelagic fishes northward into the Gulf Stream system. Larvae of billfishes (Istiophoridae) were captured in plankton tows east of the Bahamas during the first MARMAP Operational Test Phase (OPT-I) cruise in July-August 1972.[1] These captures clearly

[1]Richards, W. J., J. W. Jossi, and T. W. McKenney. Interim report on the distribution and abundance of tuna and billfish larvae collected during MARMAP Operational Test Phase cruises I and II, 1972-1973. MARMAP Contrib. 16. Unpubl. manuscr., 15 p.