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BOYD KYNARD
JOHN P. WARNER

Massachusetts Cooperative Fishery Research Unit
University of Massachusetts
Holdsworth Hall
Amherst, MA 01003

HABITAT PARTITIONING BY SIZE IN WITCH FLOUNDER, *GLYPTOCEPHALUS CYNOGLOSSUS*: A REEVALUATION WITH ADDITIONAL DATA AND ADJUSTMENTS FOR GEAR SELECTIVITY

In 1970, Powles and Kohler hypothesized separation of habitats of adult and juvenile witch flounder, *Glyptocephalus cynoglossus*, by depth based on surveys of Nova Scotia Banks and in the Gulf of St. Lawrence. Juveniles were sampled with a small mesh Icelandic shrimp trawl on the Nova Scotia Banks. These data were supplemented by data obtained from Squires' (1961) field records collected during shrimp surveys in the Cabot Strait and Gulf of St. Lawrence in the summers of 1957 and 1958 using a Norwegian deep-sea shrimp trawl. The authors concluded that during the summer months newly metamorphosed and small (<30 cm) witch flounder were found in the 180-288 m depth range.

Adult witch flounder (≥30 cm) were sampled with a No. 36 Yankee otter trawl on the Nova Scotia Banks from May to October and from November to April. Powles and Kohler (1970) concluded that adult witch flounder were most abundant at a depth range of 92-162 m. In winter months both adults and juveniles were found together in deeper water while in the summer both groups were separated.

Powles and Kohler (1970) suggested that this deepwater distribution of juvenile witch flounder could prevent direct competition with young of more abundant species such as Atlantic cod, *Gadus morhua*, and American plaice, *Hippoglossoides platessoides*, and provide a natural conservation against fishery exploitation. Their otter trawl catches, over a depth range of 36-450 m, yielded few juvenile witch flounder, although many small American plaice were captured. Escapement of juvenile witch flounder through the mesh in the wings of the trawl was ruled out because many small plaice were captured on the same grounds. The authors concluded that juvenile witch flounder were absent unless American plaice and witch flounder differed radically in behavior. Other studies of witch flounder depth distribution on the continental slope off Virginia (Markle 1975) and in the Gulf of St. Lawrence, NAFO (Northwest Atlantic Fisheries Organization) Divisions 4R and 4S (LaFleur and Lussiàa-Berdou 1982) supported the habitat separation hypothesis.

However, recent studies showed that a No. 36 Yankee shrimp trawl was more efficient in catching juveniles whereas a No. 41.5 Yankee otter trawl was more efficient in catching adult witch flounder (Walsh 1984). In that study juvenile American plaice and witch flounder co-occurred in the shrimp trawl catches; differential catches of witch flounder in the otter trawl was due to the escapement of juveniles. Apparent depth separation proposed by Powles and Kohler (1970) may have been based on data biased by gear selection.

Accurate descriptions of life history patterns of witch flounder are important for sound fisheries management, especially with regard to competition with other species and with regard to presumed mechanisms which protect from overfishing. Powles and Kohler (1970) derived their results from summer and winter surveys, and the conclusions were tentative because of potential gear selectivity problem. Therefore, I reevaluated the depth separation hypothesis with additional data taking gear selectivity into consideration.

Materials and Methods

Data used in the analysis were obtained from regular groundfish biomass surveys of the Gulf of St. Lawrence, NAFO Divisions 4R and 4S, by research vessels of the Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, during the period 1978-80. In addition, two juvenile flatfish surveys were used: one in the northern Gulf of St. Lawrence, NAFO Division 4R, 1980; and one in the areas of Hermitage Bay and Fortune Bay, NAFO Division 3Ps, in 1981 (Fig. 1).

Fishing Gears and Research Designs

Groundfish surveys in September and October of 1978-80, NAFO Divisions 4R and 4S by the *A. T. Cameron* (side trawler) were conducted with a standard No. 41.5 Yankee otter trawl with a stretched mesh size of 127 mm in the wings and reducing to 111 mm in the cod end and a 30 mm mesh cod end liner was used. A total of 188-30 min fishing sets

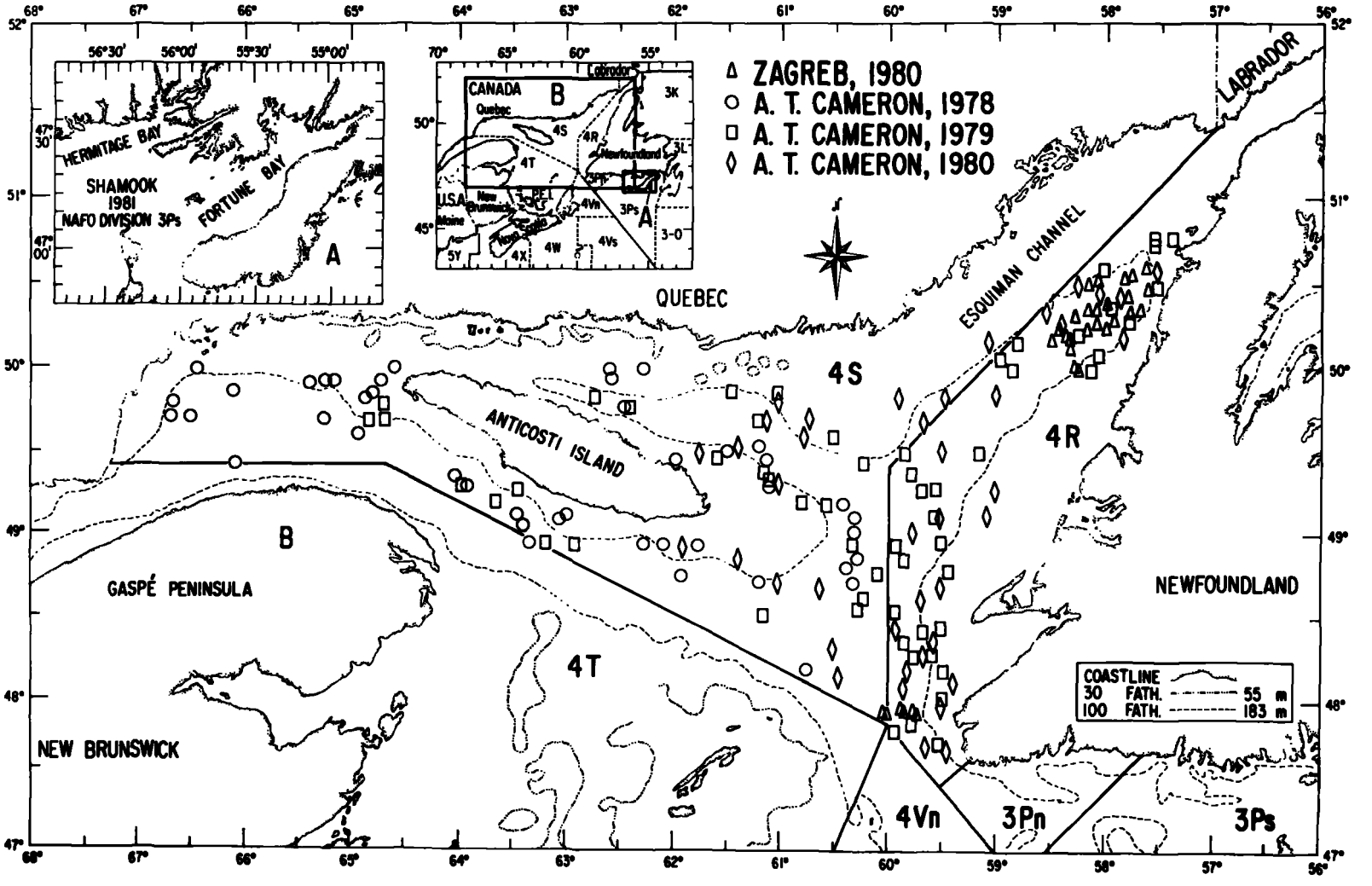

FIGURE 1.—Research vessel surveys of NAFO Division 4R, 4S, and 3Ps.

were made using a random stratification scheme (Fig. 1).

Both juvenile flatfish surveys used a No. 36 Yankee shrimp trawl, with a 38.1 mm mesh throughout and a 12.7 mm cod end mesh liner. The September 1980 survey was in the northern Gulf of St. Lawrence, NAFO Division 4R aboard the chartered stern trawler *Zagreb*. The trawl was equipped with a single tickler chain for approximately 53% of the fishing sets (see Walsh 1984). A total of 53 30-min fishing sets were made (Fig. 1). The October 1981 juvenile survey was in Hermitage Bay and Fortune Bay aboard RV *R. V. Shamook*. A total of 28 fishing sets in depths of 188-402 m were used in the analysis. Most of these sets were of <30-min duration owing to otter doors being stuck in the heavy mud of these bays and the catches were adjusted upward based on the ratio of actual tow to the standard 30 min (Fig. 1A). Both juvenile surveys were based on line transects that ran perpendicular to depth contours so that all depth zones would be sampled. Stations in the Gulf of St. Lawrence were about 10 mi apart on each line while the surveys in the two bays were about 2 mi apart. The purpose of these two surveys was to test the use of a small mesh trawl and delineate depth distribution of all flatfishes in the area sampled.

Method of Analysis

Total lengths of witch flounder were grouped into 2 cm intervals for the analysis. Catches of witch flounder at each station were divided into two size categories: juveniles (<30 cm) and adults (≥30 cm). Majority of witch flounder are sexually immature at 30 cm (Powles and Kohler 1970; Beacham 1983). Depths of catches were broken down at 20 m intervals and a Kolmogorov-Smirnov two-sample test was applied (Siegel 1956) to the cumulative distribution of both size categories for each data set. The null hypothesis used states that there is no difference in depth distribution of juvenile and adult witch flounder; i.e., the values of the population from which the juvenile sample and the adult sample were drawn have the same cumulative distribution. The alternative hypothesis used stated that there was a difference in depth distribution, i.e., the two-sample cumulative distributions were far apart and suggests the samples came from different populations. The level of significance used was $\alpha = 0.05$. A catch frequency was calculated for each size group over 20 m depth intervals.

The analysis was used on five data sets: 1) otter trawl catches for 1978-80 in both Division 4R and Division 4S were combined to increase sample size and coverage of the Gulf of St. Lawrence; 2) otter trawl catches in Division 4R, 1980 were used to compare with 3) shrimp trawl catches in Division 4R, 1980; 4) shrimp trawl catches in Division 3Ps; and 5) combination of the catches of both gears from sets north of lat. 50°N in Division 4R, 1980. The latter combination of data was used for two reasons: 1) There were no successful sets made by the shrimp trawl in depths <180 m owing to rough bottom while the otter trawl had sets in depths as shallow as 120 m, both vessels were in the same area at the same time, and 2) given a bias in gear selectivity, combination of catches of both gears should be representative of the population located in this small area of northern Esquiman Channel (Fig. 1).

Results

Trends in depth distribution of witch flounder using different fishing gears showed no significant difference in the cumulative distributions of juvenile and adult witch flounder in all data sets ($P > 0.05$) (Table 4).

No. 41.5 Yankee Otter Trawl

Divisions 4R and 4S, 1978-80. Juveniles were found in a depth range of 102-464 m with a median located in the 241-260 m depth interval. Adults were distributed in a depth range of 91-484 m with the median located in the 181-200 m depth interval (Table 1, Fig. 2A).

Division 4R, 1980. Both juveniles and adults were distributed in a depth range of 122-464 m. Most of the juveniles were located in the 241-260 m depth interval while the median of the adult witch flounder was located in the 160-180 m depth interval (Table 1, Fig. 2B).

No. 36 Yankee Shrimp Trawl

Division 4R, 1980. Juvenile and adult witch flounder were widely distributed in a depth range of 187-502 m. The median of juveniles was located in the depth interval 241-260 m while for adults it was the 261-280 m interval (Table 2, Fig. 2C).

Division 3Ps, 1981. Juvenile and adult witch flounder were widely distributed in a depth range of 188-402 m. The median of juvenile distribution was in the 281-300 m interval while that for adults was in the 261-280 m interval (Table 2, Fig. 2D).

TABLE 1.—Cumulative frequency of juvenile (<30 cm) and adult (≥30 cm) witch flounder catches over 20 m depth intervals using a No. 41.5 Yankee otter trawl.

Depth 20 m intervals	NAFO Div. 4R and 4S, 1978-80						NAFO Div. 4R, 1980					
	Nos. <30 cm	%	Cumulative %	Nos. ≥30 cm	%	Cumulative %	Nos. <30 cm	%	Cumulative %	Nos. ≥30 cm	%	Cumulative %
81-100	0	0	0	6	0.34	0.45						
101-120	2	0.11	0.47	4	0.22	0.74						
121-140	0	0	0.47	20	1.12	2.23	0	0	0	2	1.08	1.32
141-160	11	0.62	3.02	142	7.99	12.76	2	1.08	5.88	61	32.97	41.72
161-180	36	2.02	11.40	415	23.34	43.55	6	3.24	23.53	42	22.70	69.54
181-200	13	0.73	14.42	148	8.32	54.53						
201-220	15	0.84	17.91	82	4.61	60.61	1	0.54	26.47	7	3.78	74.17
221-240	90	5.06	38.84	59	3.32	64.99						
241-260	90	5.06	59.77	35	1.97	67.58	5	2.70	41.18	8	4.32	79.47
261-280	41	2.31	69.30	55	3.09	71.66						
281-300	38	2.14	78.14	110	6.19	79.82	3	1.62	50.00	5	2.70	82.78
301-320	9	0.51	80.23	33	1.86	82.27	5	2.70	64.71	6	3.24	86.75
321-340	9	0.51	82.33	64	3.60	87.02	1	0.54	67.65	4	2.16	89.40
341-360	5	0.28	83.49	15	0.84	88.13	2	1.08	70.58	1	0.54	90.07
361-380	31	1.74	90.70	59	3.32	92.51						
381-400	11	0.62	93.26	32	1.80	94.88						
401-420	8	0.45	95.12	7	0.39	95.40	8	4.32	97.06	7	3.78	94.70
421-440	3	0.17	95.81	6	0.34	95.85						
441-460	15	0.84	99.30	45	2.53	99.18						
461-480	3	0.17	100.00	10	0.56	99.93	1	0.54	100.00	8	4.32	100.00
481-500	0	0	—	1	0.06	100.00						
Total	430			1,348			34			151		

TABLE 2.—Cumulative frequency of juvenile (<30 cm) and adult (≥30 cm) witch flounder catches over 20 m depth intervals using a No. 36 Yankee shrimp trawl.

Depth 20 m intervals	NAFO Div. 4R, 1980						NAFO Div. 3Ps, 1981					
	Nos. <30 cm	%	Cumulative %	Nos. ≥30 cm	%	Cumulative %	Nos. <30 cm	%	Cumulative %	Nos. ≥30 cm	%	Cumulative %
180-190	210	4.69	4.91	43	0.96	21.18	10	0.91	2.70	42	3.83	5.87
191-200	—	—	—	—	—	—	—	—	—	—	—	—
201-220	135	3.01	8.07	5	0.11	23.65	9	0.82	5.12	51	4.69	12.79
221-240	640	14.29	23.04	15	0.33	31.03	31	2.82	13.48	103	9.38	26.96
241-260	1,194	26.26	50.97	18	0.40	39.90	8	0.73	15.63	112	10.20	42.37
261-280	1,209	27.00	79.25	36	0.80	57.64	28	2.55	23.18	74	6.74	52.54
281-300	372	8.31	87.95	21	0.47	67.98	110	10.02	52.83	118	10.75	68.78
301-320	98	2.19	90.25	4	0.09	69.95	15	1.37	56.87	6	0.55	69.60
321-340	242	5.40	95.91	8	0.18	73.89	15	1.37	60.92	29	2.64	73.59
341-360	29	0.65	96.58	1	0.02	74.38	105	9.56	89.22	174	15.85	97.52
361-380												
381-400												
401-420	—	—	—	—	—	—	40	3.64	100.00	18	1.69	100.00
411-440												
441-460												
461-480	76	1.70	98.36	39	0.87	93.60						
481-500	19	0.42	98.81	2	0.04	94.58						
501-520	51	1.14	100.00	11	0.25	100.00						
Total	4,275			203			371			727		

No. 36 Yankee Shrimp Trawl Combined with No. 41.5 Yankee Otter Trawl

Division 4R, North of Lat. 50°N, 1980. The median of juvenile distribution was located in the 240-260 m interval while that for adults was located in the 180-200 m depth interval (Table 3, Fig. 3).

Discussion

The results of the analysis do not statistically support the hypothesis that juvenile witch flounder prefer a deeper water habitat than adults, although the median usually shows adults shallower than juveniles. Only the shrimp trawl catches in NAFO Division 4R, 1980 show juveniles shallower than adult witch flounder (Fig. 2C). Combining the data

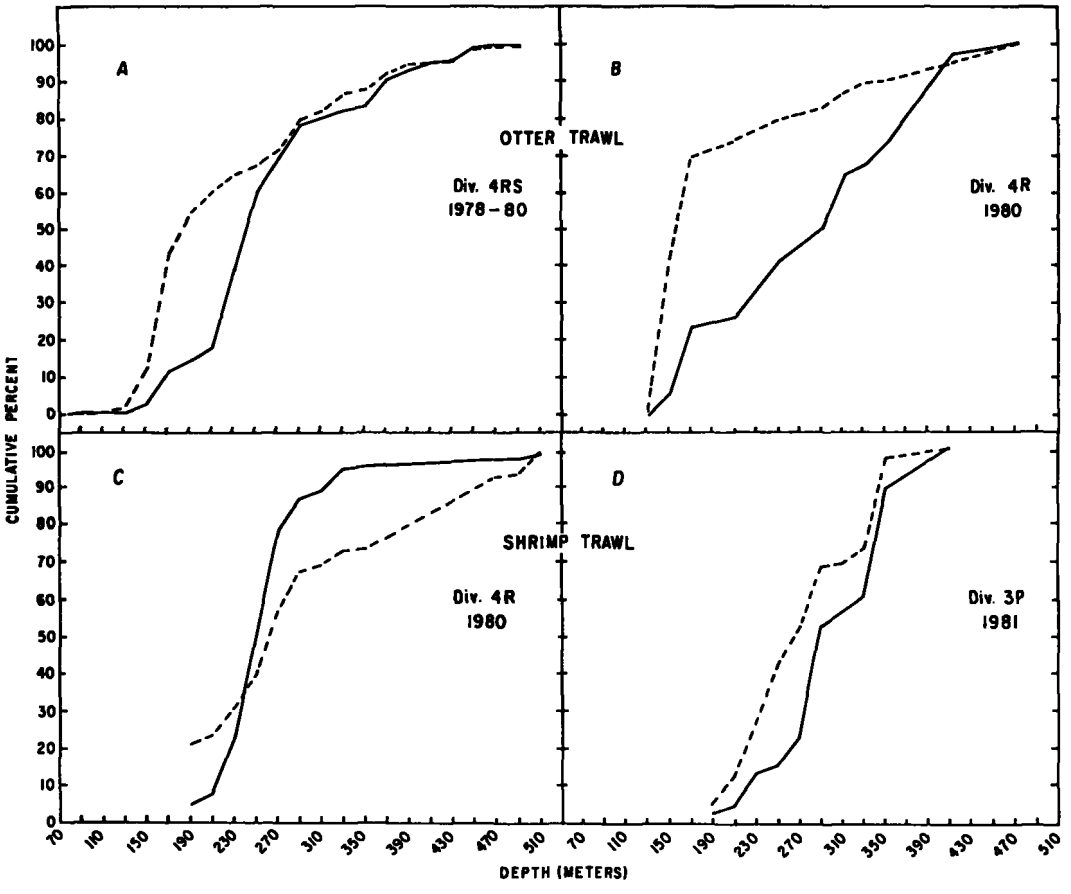

FIGURE 2.—Cumulative frequency distribution of juvenile and adult witch flounder by both fishing gears. Dash line: adults (≥30 cm); solid line: juveniles (<30 cm). A) No. 41.5 Yankee otter trawl, Division 4RS 1978-80 combined. B) No. 41.5 Yankee otter trawl, Division 4R 1980. C) No. 36 Yankee shrimp trawl, Division 4R, 1980. D) No. 36 Yankee shrimp trawl, Division 3Ps, 1981.

sets from two fishing gears for analysis of the northern Esquiman Channel area of NAFO Division 4R in 1980 takes into account biases in gear selectivity (Fig. 3). In this study of the Gulf of St. Lawrence, juveniles are more vulnerable to shrimp trawls as Powles and Kohler (1970) showed in their study. Low catches of adult witch flounder in all data sets indicate that they are widely dispersed and not readily accessible in any large numbers regardless of fishing gears used. A discrete separation of adults and juveniles does not exist. Although a large percentage of adult witch flounder are found

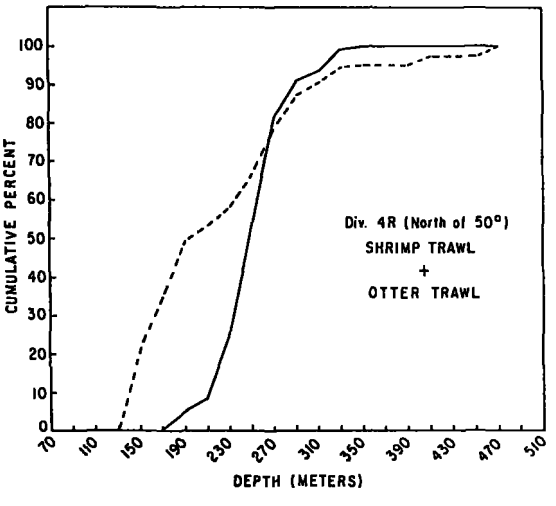

FIGURE 3.—Cumulative frequency distribution of juvenile and adult witch flounder in the Northern Esquiman Channel area (north of lat. 50°N). Catches of a No. 41.5 Yankee otter trawl and No. 36 Yankee shrimp trawl combined. Division 4R, 1980.

TABLE 3.—Cumulative frequency of juvenile (<30 cm) and adult (≥30 cm) witch flounder catches over 20 m depth intervals. Catches of a No. 41.5 Yankee otter trawl (8 sets) and a No. 36 Yankee Shrimp trawl (48 sets) combined for the northern Esquiman Channel area (lat. 50°N).

Depth	NAFO Div. 4R, 1980: Sets north of 50°N					
20 m intervals	Nos. <30 cm	%	Cumulative %	Nos. ≥30 cm	%	Cumulative %
120-140	0	0	0	2	0.04	0.66
141-160	2	0.09	0.05	61	1.37	20.86
161-180	6	0.13	0.19	42	0.94	34.77
181-200	2.0	4.70	5.24	43	0.96	49.01
201-220	136	3.05	8.50	12	0.27	53.98
221-240	640	14.33	23.88	15	0.34	57.95
241-260	1,199	26.85	52.68	26	0.58	66.56
261-280	1,209	27.08	81.72	36	0.81	78.48
281-300	375	8.40	90.73	26	0.58	87.09
301-320	103	2.31	93.20	10	0.22	90.40
321-340	243	5.44	99.04	12	0.27	94.37
341-360	31	0.69	99.78	2	0.04	95.03
361-380	—	—	99.78	—	—	95.03
381-400	—	—	99.78	—	—	95.03
401-420	8	0.18	99.98	7	0.16	97.35
421-440	—	—	99.98	—	—	97.35
441-460	—	—	99.98	—	—	97.35
461-480	1	0.02	100.00	8	0.18	100.00
Total	4,163			302		

TABLE 4.—Results of Kolmorgov-Smirnoff two sample test on each data set. Level of significance used was $\alpha = 0.05$.

Fishing gear	Year	NAFO Divisions	Total no. juveniles	Total no. adults	D statistic	Table value	Significant at $\alpha = 0.05$
No. 41.5 Yankee otter trawl	1978-80	4RS	430	1,348	0.4270	0.0753	Not significant
No. 41.5 Yankee otter trawl	1980	4R	34	185	0.4770	0.2582	Not significant
No. 36 Yankee shrimp trawl	1980	4R	4,275	203	0.2220	0.0977	Not significant
No. 36 Yankee shrimp trawl	1981	3Ps	371	727	0.2936	0.0868	Not significant
No. 41.5 Yankee otter trawl + No. 36 Yankee shrimp trawl	1980 Sets north of lat. 50°N.	4R	4,163	302	0.4448	0.0810	Not significant

shallower than juveniles in the 100-200 m range, they are also found in sufficient numbers in all depths >200 m (Table 1). LaFleur and Lussiàa-Berdou (1982) research surveys in the Gulf of St. Lawrence using a Yankee 41.5 otter trawl found juveniles in the 200-300 m depth range and, while supporting Powles and Kohler's (1970) depth separation hypothesis also noted that even at depths >300 m, a significant proportion of adult witch flounder were caught. W. R. Bowering (Department of Fisheries and Oceans, St. John's, Newfoundland, pers. commun. 1986) has found that adult witch flounder in NAFO Division 2J3KL also exhibit two peak concentrations: one at 101-200 m and a second one in depths >300 m. That adult witch flounder are not concentrated during summer months is the reason why an economical commercial fishery only occurs during winter months (Powles and Kohler 1970; Bowering and Pitt 1974; Bowering and Brodie 1984).

Catches of witch flounder in the 1981 shrimp trawl survey of the two deepwater bays in NAFO Division 3Ps shows that although adults are usually average shallower than juveniles, they are also dispersed across deeper depth zones (Table 1). This suggests that in confined areas of deepwater bays, distribution patterns of adult witch flounder is more concentrated than in large open areas like the Gulf

of St. Lawrence. Similarly, adult witch flounder have been reported concentrated in the deepwater of St. Georges Bay, NAFO Division 4R during the summer months where a localized fishery occurs in depths of 300 m (Bowering and Brodie 1984).

In conclusion, juvenile witch flounder are distributed differently than the adult population off continental shelf areas of the Gulf of St. Lawrence. However, the two populations are not discretely separated as proposed by Powles and Kohler's (1970) niche separation hypothesis. Bowers (1960) concluded that witch flounder in the Irish Sea have no definitive separation. Heavy exploitation of juvenile witch flounder is prevented by the behavior of this size group making them less vulnerable to commercial otter trawls. The difference may be related to difference in preferred food items or distribution of predators. Further research is required to establish the mechanisms for the difference in depth distribution documented by this study.

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S. J. WALSH

Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1, Canada

MOVEMENT OF TAGGED LINGCOD, *OPHIODON ELONGATUS*, IN THE PACIFIC NORTHWEST

Lingcod, *Ophiodon elongatus*, is a commercially and recreationally important West Coast species. Most previous studies have indicated that lingcod is a relatively nonmigratory species (Hart 1943; Chatwin 1956; Phillips 1959). More than 90% of the adults remained within 5 mi (8.1 km) of the point of tagging for as long as several years.

We tagged lingcod in the eastern Strait of Juan de Fuca and near San Juan Island, WA, from 1976 and 1981. We present results from tags returned by fishermen through 1985. The tag returns were analyzed primarily to show the extent of migration. We also analyzed recaptures by sex, size, direction of movement, and the effects of tag type and the location of tagging.

Methods

From 1976 to 1978, relatively small numbers of lingcod were tagged, incidental to a tagging study directed to rockfish (*Sebastes* sp.) (Mathews and Barker 1984), in which rod-and-reel with artificial lures was used to capture fish for tagging. From 1979 to 1981 tagging effort was for lingcod using a chartered commercial vessel trolling with a string of 6-10 jigs or other artificial lures from a hydraulic gurdy.