Site Fidelity in Pacific Halibut (*Hippoglossus stenolepis*)

P.N. Hooge & S.J. Taggart

USGS, Alaska Biological Science Center, Glacier Bay Field Station, P.O. Box 140, Gustavus, Alaska 99826

ABSTRACT

Pacific halibut are thought to be a widely migrating and panmictic species, yet communities in Alaska have experienced declining harvests from nearby areas. This "local depletion" has been occurring despite evidence from population models that Pacific halibut in the North Pacific can sustain harvests much higher than current levels. We placed wire tags (N = 1609) and sonic tags (N = 97) on Pacific halibut in Glacier Bay, Alaska, to determine the degree of within- and between-year site fidelity of this species. We found that most halibut exhibit both site fidelity and home range behavior. Home range size decreased with increasing age, and older individuals exhibited increased site fidelity. Sonic-tracking over multiple years demonstrated that many halibut return to the same areas in subsequent years. Data from wire tags corroborated the results from the sonic-tracking study, with 96% of fish tagged in Glacier Bay recaptured within the same statistical unit. These results suggest that Pacific halibut exhibit much more attachment to particular areas than previously thought, and that these movement patterns should be considered in the management of this species.

INTRODUCTION

Photo by J. Brooks

Pacific halibut are large (up to 3 meters long) commercially important predatory flatfish in the family Pleuronectidae. Long-distance movements of Pacific halibut have been emphasized in several studies, (Skud 1977, St. Pierre 1984) and most population models developed for the commercial and sport fisheries of this species assume relatively unrestricted movements between areas (Deriso and Quinn 1983, Quinn et al. 1985). However, the home range and movement patterns of post-juvenile halibut have not been studied other than through single recaptures of marked individuals. Recently several communities in Alaska have experienced decreasing commercial and sport halibut landings from the waters immediately adjacent (and most accessible) to these towns. Such reports suggest that intensive concentrated fishing effort is causing local depletion near human settlements, at the same time that the annual U.S. and Canadian quota is currently being increased approximately 50% by the International Pacific Halibut Commission (IPHC). The IPHC divides the overall North Pacific quota into several large statistical regions, but does not manage for more localized stocks.

Glacier Bay, Alaska, is the site of an established and extensive commercial halibut fishery that is being studied by USGS because of controversy over the commercial harvest within a National Park. In this paper we present data, gathered from sonic-tracking and wire-tagging of Pacific halibut in Glacier Bay National Park, that indicate many individuals exhibit site fidelity and restricted movements and that large-scale movements by this species may occur much less frequently than previously thought.

METHODS

The study was conducted in Glacier Bay, Southeast Alaska (59° N, 136° W), a recently deglaciated (between AD 1700-1970) Y-shaped fjord estuary with deep marine basins (200-500 m) terminated by remnant relatively shallow moraines, and with tidewater glaciers at the heads of the fjords. The bay comprises approximately 1225 km^2. The oceanography of the bay is characterized by high sedimentation (Cowan and Powell 1990) and glacial freshwater runoff, with areas of cold water upwelling and complete mixing due to strong tidal currents. As a result, primary productivity levels are high overall, with salinity, temperature, and light penetration decreasing towards the heads of the fjords.

Pacific halibut were caught using standard commercial long-line gear designed for the halibut fishery, with a soak time of 6 hours. We measured then marked 1,609 halibut with coded wire tags. Crystal-controlled, high power, ultrasonic (35 kHz) transmitters (Sonotronics: Tucson, Arizona) were surgically implanted into 97 of these halibut. The tags were 95 mm x 34 mm cylinders that weighed 108 g, approximately 0.01% of the weight of the smallest halibut tagged. Equipment and tags were sterilized. Seawater was pumped past the gills during the 5-10 minute surgery. A 5-cm incision was made and the tag inserted into the intestinal cavity. Seven to eight external sutures (2-0 Braunamid non-absorbable) were used to close the incision. The sonic tags had an expected lifetime of 2-3 years (observed range 2.5-3.4), and each transmitted a unique identifying sonic pulse.

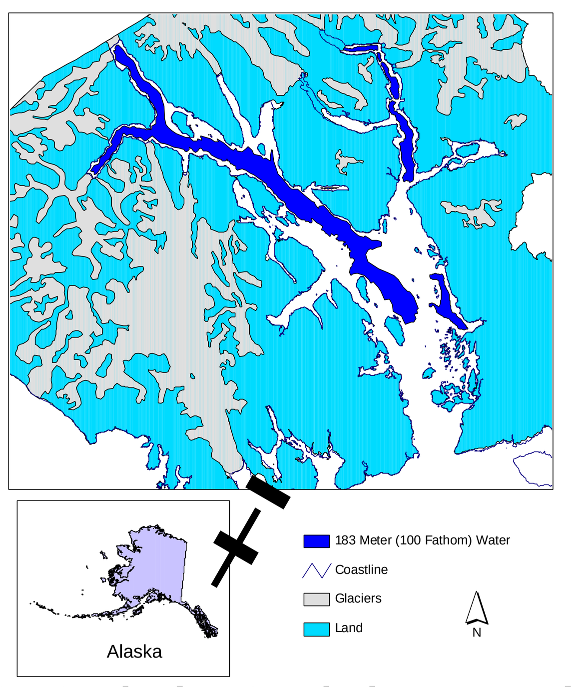


Fig. 1. The location, bathymetry, and glaciers of Glacier Bay National Park.

The halibut were tracked from a vessel using a bow-mounted dual hydrophone capable of being lowered 2 meters and rotated 360°. One hydrophone faced forward and slightly down (10° off the horizontal) and the other hydrophone pointed straight down. We used USR-4D manual receivers and DH-2 directional hydrophones with a beam width of ± 6° and a sensitivity of -84 dBV (all Sonotronics). The hydrophone assembly and the 35 kHz frequency allowed us to locate tags with 100% detection at distances of 2 km and depths to 500 m, despite much bubble resonance due to the characteristics of the water column. The dual hydrophones and the use of encrypted Y-code GPS receivers (Rockwell: Costa Mesa, California) enabled us to find tags with a 95% circular error of probability of ± 5 m at 10 m depth and ± 10 m at 50 m depth.

Photo by J. Brooks

A 3-year sonic tag just prior to insertion.

Two studies were conducted. The first concentrated on obtaining frequent positions of sonic-tagged halibut in order to determine home range characteristics. In this study we tagged 26 fish that we attempted to follow on a daily or weekly basis by searching in an outward spiral from each individual's last known position. Consequently, if a tagged halibut moved a few kilometers away, it was not necessarily found. The second study was designed to detect multi-year site fidelity and to obtain information on the movement patterns of those individuals (mainly smaller halibut) that we were unable to track due to their disappearance to the limited searching ability of the first study. The second study, of 71 tagged halibut, was conducted by establishing a network of stations spaced 2 km apart throughout Glacier Bay. The searching vessel occupied each station and then rotated the hydrophone assembly 360° while listening for sonic tags. When a tag was heard, the vessel operator maneuvered the vessel until it occupied a position directly above the sonic tag to obtain a GPS location and depth. The same network of stations was used for all searches. Searches were conducted every 2-3 months for four years.

The tracking vessel with bow-mounted retractable rotating dual hydrophone.

To determine whether individuals exhibited site fidelity we used a modification of the Monte Carlo method of Spencer et al. (1990). We modified the random walk part of the simulation to more accurately reflect actual daily movement rates and the constraints of habitat. Instead of randomly bootstrapping the distances traveled from the pool of observed distances, we used the actual sequence of distances and only randomly varied the direction of travel. In addition, we constrained the random movement paths exclusively to suitable habitat (i.e. water). Both modifications reduce the possibility of test results spuriously indicating site fidelity.

We used two techniques to quantify home range patterns. We determined the minimum convex polygon size for comparisons with other studies, and for a measure of the largest extent of area the animals traversed. To more accurately describe the shape and size of the home range and to make statistical comparisons we used the nonparametric fixed kernel home range method (Worton 1989). We used the 95% kernel to describe the area actually used by the animals, and the 50% kernel for the core activity centers and statistical tests. We used a minimum of 25 points to calculate each kernel home range. We based this criterion on bootstrapped samples from 10 halibut for which we had more than 50 locations. For the bootstrapped data the means and standard deviations stabilized after 25 location data points. This pattern is similar to that seen by Seaman and Powell (1996) using the fixed kernel method.

The statistical and home range analyses in this paper were conducted using a program extension (Movement.avx) to the ArcView Geographic Information System. This extension (Hooge and Eichenlaub 1998) is available on the Internet at www.absc.usgs.gov/glba/gistools.htm or directly from the author.

RESULTS AND DISCUSSION

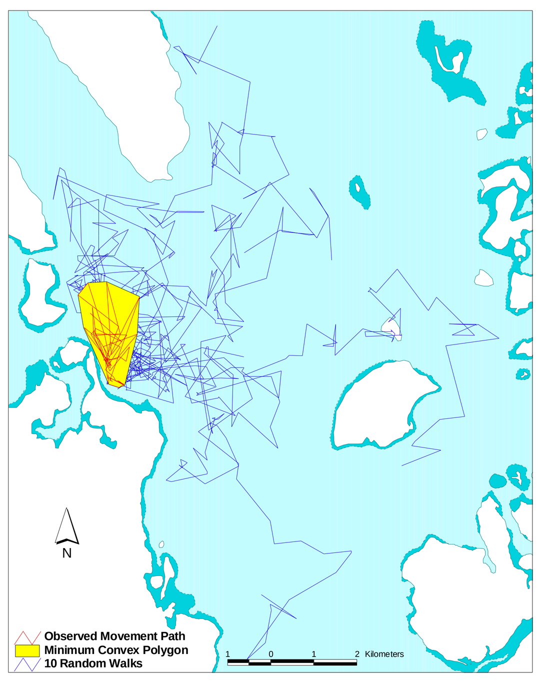


Fig. 2. All halibut for which we obtained more than five positions exhibited site fidelity as determined by comparing actual movement paths to Monte Carlo simulations of random movement paths (Monte Carlo comparison of mean squared distance from the center of activity: N = 76, all $P < 0.05$). This figure shows the actual movement path of one individual and 10 of the 1,000 simulated movement paths.

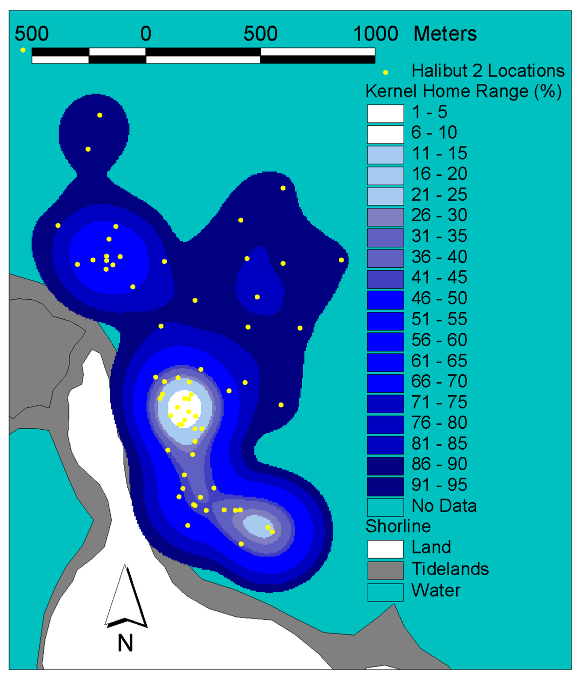


Fig. 3. Many halibut exhibited small home ranges. Of those individuals for which we had enough sample points (N=26), 54% occupied only one home range during a year, 19% shifted home range once, and 27% occupied multiple sites. Many of the latter returned to previously occupied sites. Halibut did not use all areas of the home range equally. The home range of Halibut #2, shown here, has two main activity locations. The more frequented location, to the south, was utilized throughout most of the season. Halibut #2 then shifted its focus of activity to the north. Kernel values refer to the probabilities of the animal being found within that concentric area.

Fig. 4. Minimum convex polygons (MCP's) of the 26 halibut with enough locations to determine home range characteristics. Some halibut shifted their home ranges during the season or between years. Average MCP size was 0.69 km^2, and the 95% kernel home ranges averaged 0.37 km^2. Home range size decreased with increasing halibut size (Spearman's Rho = 0.321, $P < 0.05$). The average MCP area that halibut occupied during the entire time tracked, including home range shifts within and between years, was 10.8 km^2 (N = all 97 tagged individuals).

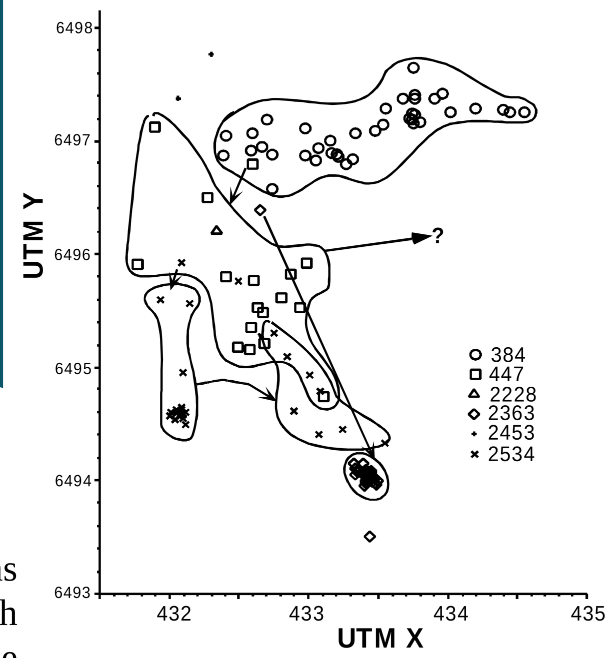
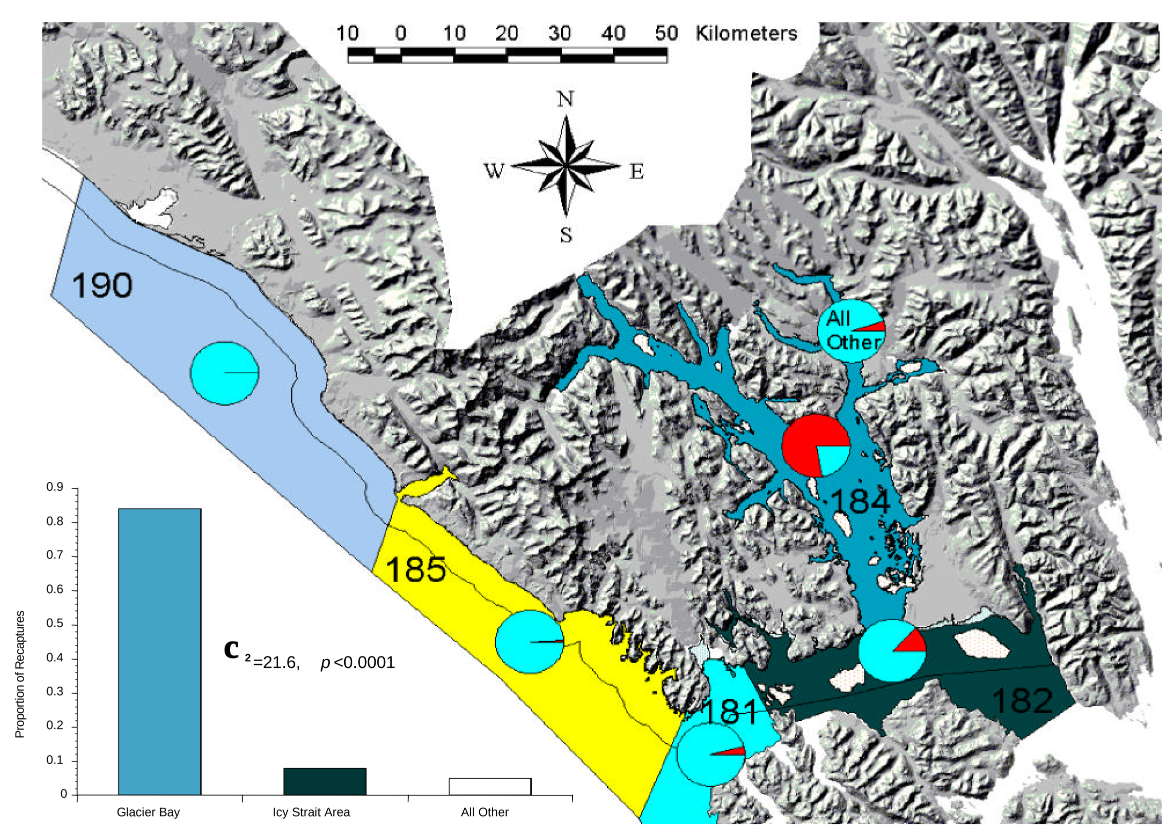


Fig. 5. Home ranges of the larger site-faithful halibut were found rarely to overlap simultaneously. These six individuals were caught on the same long-line set. Two tags (#2228 and #2453) were lost to the fishery. Although two of the home ranges overlapped spatially, they did not coincide temporally; Halibut #2534 moved to the home range of Halibut #447 only after the latter had left (or had been caught in the fishery).



χ^2=21.6, p<0.0001

Fig. 6. Data from wire tags (N = 136) corroborated the results of sonic tracking. For halibut tagged in Glacier Bay (IPHC Statistical Unit 184), 96% of those recaptured were within the Glacier Bay or adjoining Icy Strait (Unit 182) areas. For the tagged individuals with precise recapture information, the average distance between points of capture and recapture was 2.8 km (N = 14).

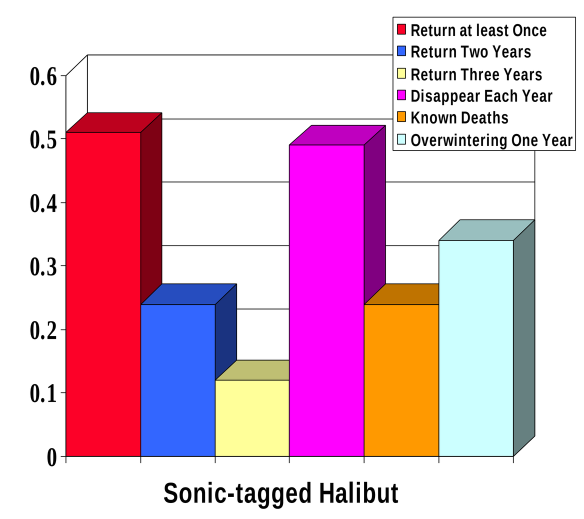


Fig. 7. Halibut are thought to travel to areas outside the Park to spawn during winter. Many halibut returned to the same home ranges or nearby areas in subsequent years. Given known mortality, less than 26% of halibut did not return. This number is probably conservative as indicated by wire-tag returns and other factors such as failure of sonic tags and the destruction or relocation of commercially harvested tags.

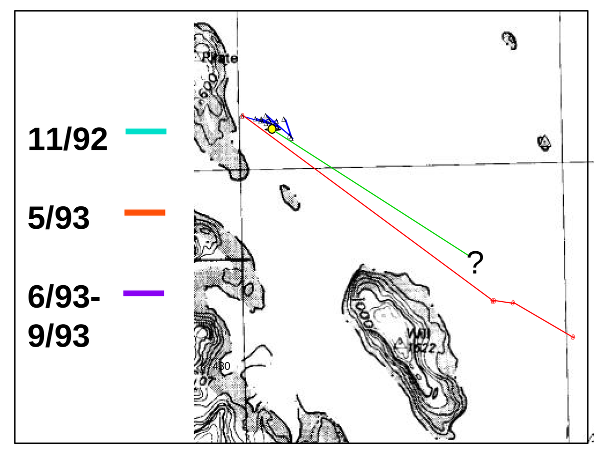


Fig. 8. This figure illustrates the return of one of our sonic-tagged halibut to the same area in the subsequent year. The yellow dot is the original capture point in 1992. In another case, not shown here, an individual transplanted 12 kilometers from its capture point returned in three days to within 100 meters of the original point of capture.

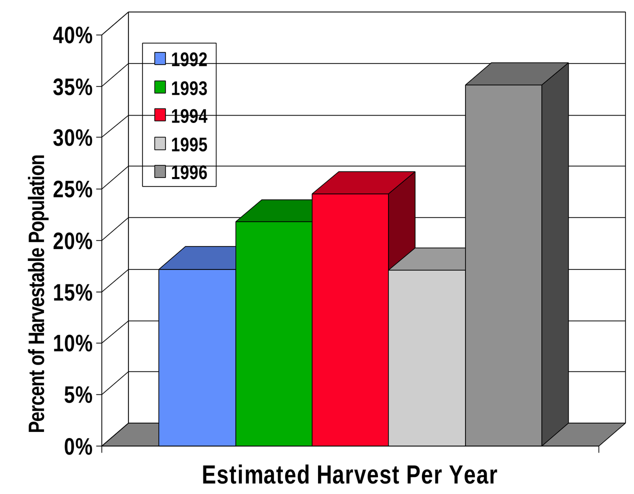


Fig. 9. Harvest rates of halibut have increased significantly in Glacier Bay National Park with the start of the Individual Fishing Quota (IFQ) fishery (after 1995), which removed much of the impetus for fishers to travel farther from local areas. The old fishery, which occurred in very short openings, forced fishers to disperse. In addition, the market has shifted from frozen to fresh product.

Halibut population models suggest that the entire population of halibut is being under-fished (Clark et al. In Press). The IPHC is increasing the harvest quota by 48%. This increased quota, combined with the site fidelity and small home ranges indicated by our studies and the increased local harvests since the creation of the IFQ fishery all raise the likelihood that areas near population centers will experience local depletion of halibut stocks. The Southeast Alaskan community of Sitka recently closed its nearby waters to commercial fishing for part of the year in response to just such a decline in local harvest rates.

ACKNOWLEDGMENTS

We thank G. Bishop, L. Chilton, C. Dezan, F. Koschmann, E. Solomon, and L.J. de la Bruere for their help in the field, and E. Ross Hooge for editing this paper. This work was funded by the USGS Biological Resources Division and the National Park Service, and was conducted in Glacier Bay National Park with the permission of the National Park Service.

LITERATURE CITED

Clark, W.G., S.R. Hare, A.M. Parma, P.J. Sullivan & R.J. Trumble. In Press. Decadal changes in growth and recruitment of Pacific halibut (Hippoglossus stenolepis). Canadian Journal of Fisheries and Aquatic Science.

Cowan, E.A. & R.D. Powell. 1990. Suspended sediment transport and deposition of cyclically interlaminated sediment in a temperate glacial fjord, Alaska, U.S.A. In: Dowdeswell, J.A. & J.D. Scourse (eds). Glacimarine environments: processes and sediments. Geological Society, London, pp. 75-89.

Deriso, R.B. & T.J. Quinn II. 1983. Estimates of biomass, surplus production, and reproductive value. International Pacific Halibut Commission Science Report 67:55-89.

Hooge, P.N. & W.M. Eichenlaub. 1998. Animal movement extension to ArcView. Ver.1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage, AK, U.S.A. Available: http://www.absc.usgs.gov/glba/gistools.htm.

Quinn II, T.J., R.B. Deriso & S.H. Hoag. 1985. Methods of population assessment of Pacific halibut. International Pacific Halibut Commission Science Report 72: 52 pp.

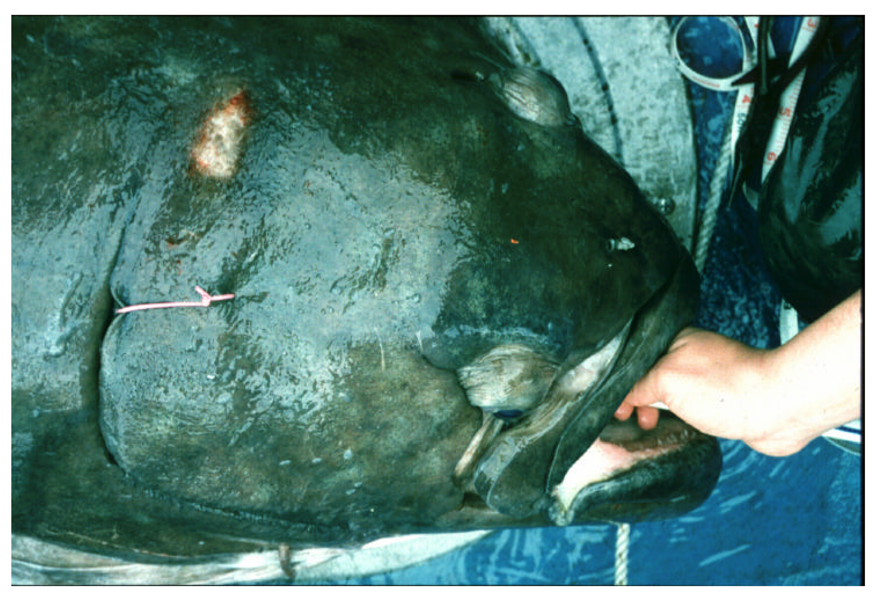
Seaman, D.E. & R.A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology (Washington D C) 77:2075-2085.

Skud, B.E. 1977. Drift migration and intermingling of Pacific halibut stocks. International Pacific Halibut Commission Science Report 63: 42 pp.

Spencer, S.R., G.N. Cameron & R.K. Swihart. 1990. Operationally defining home range: temporal dependence exhibited by hispid cotton rats. Ecology 71:1817-1822.

St-Pierre, G. 1984. Spawning locations and season for Pacific halibut. International Pacific Halibut Commission Science Report 70: 46pp.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.



Open wide and say "ahhh."