Flatfish

It was a double-hulled ten-foot fishing boat, open to the sky, powered by an outboard motor, seaworthy enough for Puget Sound if not the wilder parts of the Salish Sea. At Three Tree Point south of Seattle calm waters prompted three generations — a seven-year-old boy, a mother, and a grandfather — to launch the sturdy boat. As the craft began to float, the youngest of the three climbed in, gear in hand, ready to go. The older companions proceeded at a more cautious pace, making certain that all the necessary gear was loaded, including life jackets, anchor, food and water, bait, poles, warm clothes. One did not venture onto this inland sea without caution, even on days when the wind barely whispered and the water glimmered rather than tossed.

The fishing began with a try for salmon, always a long shot, as it was on that day. But it was fun nevertheless, and there was always that other option. Flatfish. Flounders and sole, tasty white fish that at least one of the fishers liked better than salmon anyway. Large size was not expected, but failure to pull at least one of these strange creatures upwards into an oversized net was not an option for the young boy. We might fish for the entire day.

Yet the wait was not too long, and soon we had a few flatfish in our waiting bucket. They were quite beautiful, dark on the top, white beneath, with small, rounded mouths. And oh, those eyes. Both looking upward. Had they seen the bottom of the boat? Or was their attention simply focused on the small piece of herring, dangling near the sea floor?

To fish in the cold waters of Puget Sound and to bring home a number sufficient for a healthy meal enjoyed by our small family was a blessing not to be forgotten. I could only hope that care would provide equal opportunity for the generations to come. And that the descendants of that odd creature we pulled from the sea would continue to thrive.

Named for the shape of their bodies, the pancake-like flatfish form offers protection at the bottom of the sea, where the fish can lie flat or dig into soft substrate. Camouflaged by colors that blend well with the habitat, the strange creatures seem doubly protected. And the method has been well-tested, for over the eons of their existence, it seems likely that countless fish sought shelter on the sea floor by flipping on a side in their attempt to confuse a predator, or perhaps to provide a cover from which to hunt. These innovators occasionally buried themselves, pushing sand and gravel aside with their fins and tails, revealing only their eyes.

In time, the flatfish — the flounders, the soles, halibuts, turbots, and more — would compose a group not only with a unique body shape, but for a tendency to remain on the ocean floor, altering their form and behavior for this permanent home. And a prolonged residency on the bottom led to new evolutionary processes, ones that may have occurred in a relatively short time, as these changes go.

But there was at least one problem with the new lifestyle. For a fish on its side, buried in the sand, what would become of the eye that touched the ground? At the very least it would seem to become blurred with sand and mud; at the worst infected or blinded. If both eyes could point upward, they would be washed by water; with the added benefit of improved vision, the new configuration seemed the best answer. And thus, the oddest flatfish feature of all evolved — a one-sided face with both eyes pointed upwards.

As the movement of eyes to the upper side of the body took place, the question of a preferred orientation was answered with “both” and, in time, flatfish would evolve two forms, the right-eyed and the left-eyed. To be one or the other doesn’t imply strength, but rather sidedness alone. Right-eyed flatfish have both eyes on the right side of the head, left-eyed the opposite.

Otherwise, similarity between species is more the norm. As an example, the underside of these seafloor dwellers is typically a pale color, whitish or cream, and the top (the eyed side) is gray to brown to greenish. The gills are symmetric, much like a conventional vertical fish, and above, the two googly eyes look upward or sometimes to the side. It isn't a bad view. Prey might swim by, unaware of the still form beneath. And sedentary flatness does not imply slowness. These bottom dwellers can quickly respond to disturbance or opportunity.

Most of the flatfish in the Strait of Juan de Fuca are right-sided fish, members of the Pleuronectidae Family, the name meaning "rib" or "side", and "swimming." Just to confuse things, however, some Pleuronectidae species are predominantly left-eyed, even though they belong to the right-eyed family. Such is the case with one of the largest, the Starry Flounder (*Platichthys stellatus*). Named for its starlike scales, this fish is unusual not only for the side that points upward but for a habitat that includes estuaries and other shallow waters.

Although primarily species of cold northern Pacific waters, the Pleuronectidae family is also represented in the Southern Hemisphere, and a few species occupy subtropical waters. There are 13 relatively common species in the Strait, a small portion of a family composed of more than 65 members and several genera.

Pacific Sand Sole (*Psettichthys melanostictus*), a right-eyed flatfish

Of those 13 flatfish species, the Pacific Halibut is by far the longest and heaviest in the Salish Sea, and reigns as the second largest flatfish in the world; only the closely related Atlantic Halibut is greater in length and weight. But other Pleuronectidae species can also attain considerable size. Large Starry

Flounder measure to 36 inches, with the Arrowtooth Flounder (*Atheresthes stomias*) coming in second at a maximum size of 33 inches and a weight of nearly 20 pounds. A few sole species can reach two feet or a bit more; these include the Rex Sole, the Rock Sole, and the Dover Sole. Small species include the English sole, which tops out at a bit over three pounds and a foot or so in length.

Representing the only member in the Strait of the left-eyed flatfish family — the Paralichthydae — the Sand Dab (*Citharichthys sordidus*) looks skyward from the left side rather than the right. As one of the smaller flat fish, with a maximum size of 16 inches, as with most others, the Sand Dab is much sought after by anglers, and can be caught from shore as well as on from a boat. Worldwide these left-eyed Paralichthydae are as numerous as the right-eyed (Pleuronectidae) and are found in tropical waters as well as cold. The Sand Dab itself is a member of a large genus of 24 species. Small size may affect longevity, for although many flatfish are very long lived, the Sand Dab lives only to an old age of nine years. Speckled to match their habitat, young Sand Dab resemble other flatfish.

Flatfish are considered tasty by species other than humans, and only the large Pacific Halibut seems to be protected by size against sea predators; this fish can achieve a weight of 500 pounds and a length of eight feet. Most species are much smaller, and every hunter in the sea likes a flatfish or two. With their home on the sea floor, the rapid movement of these fish when in pursuit of prey belies the appearance of their sedentary lifestyle. It also enables a quick return to the bottom, where camouflage and cover offer an escape.

Sometimes found in deep waters on the continental shelf, with the Arrowtooth Flounder having been recorded at depths of nearly 3,000 feet (914 m), most flatfish tend to inhabit relatively shallow waters of less than 1,640 feet (500 m). Of these, a few species are sometimes found in estuaries. Others routinely occupy the deepest waters of the Strait, and even the smallest may hunt at such depths. The young are typically found in more shallow habitats.

Several species are considered abundant, while a few are known in the Strait from single records only, although at least one of these rare Strait species is common in Puget Sound. Many species, typically the largest, are fished commercially, particularly in the open ocean. Recreational anglers tend to be cosmopolitan in their preferences and throughout the Salish Sea the white, wholesome meat is highly prized.

Naming the Soles, the Flounders, the Halibuts, and More

There is no systematic common naming convention for "sole" and "flounder." The etymology as well does not show agreement, as "sole" can mean "sandal" in Latin but is also a synonym for "tongue." In North America, the soles may not be "true" soles at all, as these are considered to belong to the Soleidae family of Europe and Asia.

"Flounder" might be a bit more consistent as they belong to the same suborder, but at least one species, formerly known as the "Lemon Flounder" or sometimes the "Lemon Sole" was officially designated as the English Sole by the California state legislature in 1949. Thus, for those fish hatched in the 1940s, they were no longer lemon nor flounder.

Other common names include "dab," but even this name does not imply uniqueness. The Sand Dab of the Salish Sea is a member of a "left-eyed" genus, the *Citharichthys*, a large group, but the dab name is not confined to this genus nor its family. Instead, these Atlantic "dabs" are members of the large right-eyed family, the Pleuronectidae. Of course, not all "dabs" go by the name; some are flounders, while others are soles.

Flatfish

The two "flounders" of the Strait are large fish, although not bigger than the largest sole, and they are members of different genera, with odd features such as body scales of two types on the Arrowtooth Flounder, and stellate scales on the Starry Flounder. The common names, referring to both as flounders, seems consistent, although sometimes the Arrowtooth is called a "turbot."

There are discussions amongst fish people that supposedly apply logic to common flatfish names, but with so many species and a long history of human use, confusion is inevitable. As an example, at least one source says that halibut are larger than flounders (and soles as well) and tend to appear diamond-shaped, thanks to pointed dorsal and anal fins. But halibuts can be small, and in any case, at least one is named a turbot as well.

Other names are applied to flatfish species: plaice, brill, megrim, and more are all part of the lexicon. Perhaps the most winsome name is "topknot," as in "Norwegian Topknot", a left-eyed fish, and at a mere 4.7 inches one of the smallest flatfish.

Given the inconsistent naming practices, when studying flatfish it may be best to learn scientific names. Or accept at the very least that what is a "sole" to you might very well be a "flounder" to someone else. And, of course, when it comes to descriptive name-calling, there is nothing quite like the "slime sole," a clever species with an obvious defensive trick of its own.

Googly Eyes and Sensitive Noses

Flatfish species may appear similar — diamond-shaped bodies, fins that extend from tail to head, dark above, pale below, eyes on the right or sometimes on the left — but all is not the same, particularly with those odd eyes. Some species can rotate their eyes in several directions, giving them a nearly 360-degree view of their surroundings; others are more restricted in movement. This variability is often related to seeking food, but flatfish do not hunt by sight alone. Smell is also important, and, for some species, the only sense employed: these fish tend to have reduced or absent pectoral fins and typically do not move above the sea floor when seeking prey.

Most flatfish species do use sight for hunting, and in addition to mobile eyes, many can raise their heads above the bottom, supported by their pectoral and anal fins. These visual feeders are more capable of consuming free-swimming prey than those that do not use sight and will sometimes hunt in the water column above.

The large Starry Flounder is a visual hunter, although in this case the smallish eyes are not particularly commensurate with the size of the fish. Decorated with tiger-striped dorsal and anal fins, this flounder is one of the most easily identified flatfish, although depending on substrate it may take on a darker form, somewhat obscuring the striping. Small-mouthed, the Starry Flounder can raise its head above the substrate, an "alert" position that provides a better view of crabs and other quick-moving prey.

Bulbous eyes are a feature of the Rock Sole (*Lepidopsetta bilineata*), a species recently "split" from the Northern Rock Sole (*L. polyxystra*). Coupled with the large eyes are thick lips; both species can flatten their eye stalks, thus blending more completely with the substrate. Although smaller than the Starry Flounder, Rock Sole can grow to 27 inches in length.

Considered a premier commercial fish for its excellent taste, the Petrale Sole (*Eopsetta jordani*) typically hunts in deep water. This species has large eyes and an equally big mouth. What does it eat? Other fishes, crustaceans, the occasional octopus or squid, and anything else that might fit into the large mouth.

Flatfish

Two-sided Identity Crisis?

Eyes on one side of the flatfish body might be sufficient to label them weird, but there are other features as well that define these unique fish. To begin with, as young mature and settle to the bottom, the "blind" side takes on a pale color, sometimes nearly white. This lack of pigment contrasts with the top ("eyed") side of the typical flatfish, which is dark, often with splotches of contrasting color. The ability to match the substrate can happen in seconds, or sometimes take hours. The change appears to be triggered by a visual response, with previous experience in a particular habitat sometimes providing the ability to modify their body more quickly. Thus, the camouflage reaction can be a dynamic response.

It is not only the flatfish eyes that migrate from one side to another, but other changes occur as well. Scale type may modify with maturity and mouths often become asymmetric, as for example with the Rex Sole, in which the jawbone is longer on the blind side. Other flatfish exhibit this feature, and some have large mucous cavities on the blind side. Fin size also may vary between top and bottom.

Metamorphizing – From Symmetry to Dichotomy

All flatfish begin life with a body much like any other newly hatched fish. And as they grow and mature into a juvenile stage, they maintain symmetry, with eyes on either side of the head and an upright form. As if reluctant to relinquish their similarities with other fish, some species hang onto this verticality for months, while others, with a fish version of a sigh, begin their slow sink downwards, eventually reaching the floor of the sea, where, with occasional excursions upwards, they will spend most of their lives.

Near the bottom, another fish species swims and hunts, but does so in the orientation with which it was born; that is, upright, and moving most often at near right angles to the solid substrate. Those companions might bury themselves to hide or escape a predator, burrowing tail first or perhaps flipping temporarily on their side, seeking purchase and cover.

Such occasional behavior for a "regular" fish might be observed with envy, if the flatfish were capable of such an emotion, because its destiny, as soon as the descent began, is to lie flat, one side down, the other side up. In the distant past, their ancestors were regular as well, but evolution favors the bold, or the innovative, and once the burying became a more frequent activity, the body began to change. Unlike its temporary associates, coming and going in response to predation or opportunity, the new form enabled more permanence, as burying was improved with altered, quick fins, while a flattened body provided subterfuge when hunting and protection when hiding. However, there was that problem of the eye located on the underside. It was of little use to a fish fully engaged in a new lifestyle, one with promise, but without assurance of long-term survival.

There must have been enough fish with a pliable genetic code that could secure a trait in response to new opportunities, for evolution apparently worked quickly in the case of flatfish, and the answer ultimately seemed so simple. Place the two eyes on the top side. One would not be missed below (now the "blind" side) and might prove an aid above. Two is better than one.

However, this process of altering a head to accommodate eyes on the same side isn't just a matter of a simple slide from side to side: the process is much more complicated. Considerable research has been devoted to not only figuring out what the genetic triggers might be, but also what physical processes are necessary. How do you change a two-sided fish to one with the appearance of a drawing by an imaginative child, or an adult in search of an artistic niche? Who would have guessed?

Besides eye movement and color changes, other alterations occur in the juvenile flatfish as it transforms orientation from vertical to horizontal. The mouth may lose its symmetry, the fins their equal size, the lateral line its prominence, and the scales their similarity on the eyed and blind sides. The olfactory organs might stay fixed in location but develop an asymmetry, with the eyed side larger than the blindside. And it isn't a matter of the eyes simply moving upward. They rotate 90 degrees, facing a new direction.

Researchers have learned that the thalamus, and in particular a tiny structure named the habenula, play a significant role in flatfish metamorphosis. This little gland may grow asymmetrically as part of the eye movement process. The change is dictated by thyroid hormones; as with other vertebrates, alterations of hormones affect morphology. During normal metamorphosis, the flatfish craniofacial remodeling, most obvious for the eye rotation, takes place along with the increased pigmentation of the eyed side of the fish. As one eye migrates to the opposite side of the head, the interocular and interaural axes (those between the eyes and the ears) become perpendicular to each other, unlike symmetric fish in which they are parallel. This gives the adult flatfish a whole new look, with eye orbits turned at right angles to ears. Apparently, these changes do not begin until the fish has settled to the bottom, support for an idea that the ancestral form was a fish with an established lateral behavior.

Other vertebrates have asymmetries as well, but their development (for example, the placement of internal organs) is confined to the embryonic stage. The flatfish continues with this process, producing a form that does not mirror internal organs, which basically remain the same, but rather involves an entirely new external configuration.

Many other aspects of flatfish metamorphosis, and subsequent behaviors linked to this reorientation continue to be subjects of research. Although much has been learned, such as the key role of identified genetic pathways and thyroid hormones, the understanding has only begun, in part because of tools newly available to modern investigations. These methods enable scientists to explore more deeply the peculiarities of flatfish form and lifestyle dictated by their unique body plan. Certainly, they are amongst the most intriguing of fishes and other animals alike.

Flatfish Offense and Defense

The extrusion of slime to dissuade attack is a defensive mechanism employed by at least one northeastern Pacific species, the Dover Sole (*Microstomus pacificus*). Although having a very slimy skin is not sufficient to prevent taking by human fishers, it is undoubtedly off-putting to other animals.

Flatfish can move very quickly when hunting, but although this acceleration from the bottom is an advantage, their inclination for an otherwise sedate life places them at risk from predators. Many of these hunters find the fish as tasty as humans do; these include marine mammals, diving birds, and big fish. Even the potentially large Dover Sole occasionally makes a fine meal for the larger Pacific Halibut. And the halibut is not completely safe either, as sharks, sea lions, whales, and other halibut eagerly hunt them. It seems that all is not safe on the bottom, where flatness might seem sufficient to prevent detection, but predators can be as clever as the fish they seek.

What is a flatfish to do? On sandy bottoms, burrowing offers a good cover, and the eyes-upward on a one-sided face provides an excellent view of the surroundings. Such an odd geometry may well have evolved in response to a regular escape to the sandy bottom. Yet at times not even such an exit is possible; what happens, for example, if a fish finds itself on a rocky or muddy substrate, where digging in may not be an option. A dark fish on a pale surface, or vice versa, finds hiding very difficult.

In such a precarious situation, the ability to change color is literally a life-saving process. Like the Ptarmigan, a northern bird that wears brown plumage in the summertime brush and white in the winter's snows, the flatfish responds to its environment.

There is speed as well. Some flatfish species are capable of surprising accelerations, whether in pursuit of prey or to escape a fate as someone else's dinner. This quick start may determine the difference between life and death, surprising the predator, providing the flatfish with at the very least a brief opportunity for escape.

The Identity Crises Continued — Scales Above and Below

As if two eyes above, skewed mouths, and contrasting colors on the eyed and blind sides, not to mention the ability to change color, were not sufficient, most flatfish species enhance their unusual appearance by having two types of scales. The scales are closely related for their form and evolutionary history, but they differ in one important way; those on the flatfish eyed side have teeth at the posterior edge, and those on the blind side do not. Collectively known as leptoid scales, the two are named cycloid and ctenoid and are the most recently evolved of fish scale types. The resemblance between them is close and the material the same, but the cycloid scales are most common in lower order fish, while the ctenoid are the predominant type of the higher orders.

Researchers have historically considered the primary purpose of scales to be for protection and locomotion. Protection includes physical factors, such as the abrasion of sand and punctures by rocks and other protruding objects, as well as predation by other species. Scales can be an aid to movement, creating a smooth surface for the flow of water or a nearly frictionless pass over sand and gravel. They are often reflective, an aid to confusing predators and prey alike. Like rings of a tree some add to their circumference each year as the fish grows, while new scales grown annually expand the cover for many species.

Although they serve similar purposes, scales differ both in form and composition. They can be composed of bone and collagen, as in the case of cycloid and ctenoid scales, or of an enamel-like dentine and an inorganic layer. Some are shaped like jigsaw puzzle pieces, while others overlap.

Not surprisingly, scales have an evolutionary history as long as that of fish themselves, meaning their origins extend back hundreds of millions of years. Scales originated with the ostracoderms, a general term for jawless fish that evolved more than 400 million years ago. Originally covered with armored plates, it was these fish that would in time develop distinctive scales. Today, most fish species are scaled, although with such a long evolutionary process the innovation underwent significant changes, resulting in the several distinct forms. A few fish, including eels, lampreys, catfish, and a Salish Sea denizen — the ratfish — are scaleless. But most are covered with at least one of the scale types, and one group, the flatfish, have two.

Fishes without bones can have scales; in the case of the cartilaginous sharks, the scales are comparable to vertebrate teeth, with a pulp cavity, blood vessels, and an inorganic surface. Yet it is the leptoid scale type that is most common, a feature of the teleosts, a group of ray-finned fish that includes 96% of all fish species present on Earth today. And of this large number, the majority are covered with ctenoid scales, although perhaps the most famous order of all, the salmons, bear the sleek cycloid scales.

Smooth to the touch, cycloid scales are beneficial to flatfish when gliding over the substrate in pursuit of prey, or perhaps a mate, or when seeking an escape from a lurking predator. Since this type of scale seems so advantageous, why, then, would flatfish, along with repositioning their eyes and modifying their color, grow the toothy (and rougher) ctenoid scales on the tops of their bodies?

At least one study investigated the dynamics of four European flatfish species, each with ctenoid scales on the eyed side, and cycloid on the blind. These fish were tested for their "critical sliding angle" (CSA) as a function of sand and gravel grain size. The spinelike teeth of the ctenoid scale proved more effective at higher angles, slowing the loss of sediment on the surface of the fish. In other words, if the fish quickly raised its body, either to hunt or to flee, its ctenoid scales would hold the sand more effectively, providing more camouflage. This could be particularly important for species which require an extended time for pigmentation alterations, offering another means of escape. And although a sand cover is not a guarantee against predation, it does provide a measure of protection for many slow-moving, sedentary fish.

Of the 13 flatfish species most common in the Strait, nine of them exhibit this scale dichotomy in adult fish. The notable exceptions include the Pacific Halibut which retains its small cycloid scales throughout its life, while the left-eyed Sand Dab is predominantly covered with the toothy ctenoid scales. One flounder — the Starry — is unique with its coat of rough, starlike scales; this is an intertidal fish, often present in brackish habitats with muddy bottoms. The Rex Sole also bears small cycloid scales as an adult, although other members of its genus mature into adults with both types.

All of these flatfish species will bury themselves in sandy or muddy bottoms, remaining visually hidden from predators, and positioned to seek prey. There they might slide most easily on the toothless smooth cycloid scales, while utilizing the rougher scales for cover. The answer to this scale dichotomy is undoubtedly not so simple, and the phenomenon is quite unique among all fishes . Along with all the other changes that transform it from an upright symmetry to a horizontal, one-sided body, the scales are one more odd feature of these other-worldly enigmatic creatures — the flatfish.

On the floor of the sea the large flounder lays its body down, swirling the sand into a protective cover, until only its eyes are visible. Above, conventional vertical fish swim about, sometimes in groups, often alone, pushing currents of water over their gills with their constant motion, extracting life-giving oxygen. The flounder shares at least one symmetry with its frenetic, distant relatives. Its gills are the same size, for this is one feature evolution retained. As with other fish, these gills must be bathed in a flow, and thus the flounder must pump water over them. Sometimes it raises its body and moves, as quickly as any other fish, ejecting water through its gills for an extra push. It would seem that flatfish life cannot be so sedentary after all.