生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	鰭運動有助於向後和向前游泳 Fin movements aid in swimming backward and forward
生物系統 LIVING SYSTEM	非洲刀魚 African knifefish *(Gymnarchus niloticus*) belly fin
功能類別 FUNCTIONS	#在液體中移動 #在液體中導航 #move in liquids #navigate through liquid
作用機制標題	刀魚波浪狀的鰭使其能夠向前和向後游泳，並通過產生推進水射流使其漂浮。 (The undulating fin of the knifefish enables it to swim forward and backward, as well as keep it afloat, by creating propulsive water jets.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	

作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)

憑藉其光滑、流線型的身體和長長的腹鰭，對於非洲刀魚（*Gymnarchus niloticus*）來說，在水下移動似乎很簡單。然而，它比乍一看要復雜得多。刀魚必須嚴重依賴其長長的腹鰭來保持其移動和漂浮，因為其尺寸過小的側鰭無法提供在水中所需的升力。幸運的是，這種魚鰭在運動方面是動物界的奇蹟，它可以讓魚快速向各個方向移動——包括向後移動。

With its slick, streamlined body and long belly fin, moving around underwater may seem simple for an African knifefish *(Gymnarchus niloticus*). It is, however, a lot more complicated than how it appears at first glance. The knifefish must heavily rely on its long stomach fin to keep it both moving and afloat, as its undersized side fins don't provide the lift needed in the water. Fortunately, this fin is a marvel in the animal world when it comes to movement, allowing the fish to quickly move in all directions–including backward.

這些運動都是通過鰭能夠承受的不同類型的波動（波浪狀運動）來實現的，如本影片所示。類似於人的手臂或腿，魚的鰭是由肌肉控制的，正是由於這些肌肉，刀魚的腹鰭才能以這種方式移動。通過沿著鰭從魚的前部到後部發送波動（想像體育愛好者在體育比賽中揮動的波浪），水被攪動，形成向後的射流，將魚向前推。反過來，從後向前擺動鰭，將水向魚的前面攪動，產生向前的射流，將魚向後推。

These movements are all achieved with different types of undulations (wave-like movements) that the fin is able to undergo, as in this video. Similar to a human arm or leg, the fins of a fish are controlled by muscles, and it is thanks to these muscles that the stomach fin of the knifefish is able to move in such a way. By sending undulations (picture sports fans doing the wave during a sports game) along the fin from the front to the back of the fish, the water is churned up, creating a backward directed jet that pushes the fish forward. In reverse, undulating the fin from the back to the front churns up the water toward the front of the fish, creating a forward-directed jet, which pushes the fish backward.

然而，保持在原地有點複雜，因為必須啟動兩個相等的波形。這兩個波浪必須沿著魚鰭形成，從魚的兩側開始，在中間匯合。一旦兩個波浪相遇，向前和向後的射流都會抵消，水被向下推，形成一個新的向下射流，通過向上推動魚來防止魚下沉。結合使用這些不同的起伏模式，刀魚能夠快速平穩地向前或向後移動。

Staying in place, however, is a bit more complicated, as two equal waveforms must be initiated. These two waves must be created along the fin, starting from the opposite sides of the fish, and meeting in the middle. Once the two waves meet, both the forward and backward jets cancel out, and water is pushed downward, creating a new downward jet that keeps the fish from sinking by pushing it upward. Using these different undulation patterns in combination, the knifefish is able to move quickly and smoothly forward or backward.

文獻引用 (REFERENCES)

"The fish exhibits inward counter-propagating waves [two separate waves that travel from opposite ends of the body, meeting in the middle] typically when it is hovering – staying stationary with active stabilization against perturbations." (Curet et al., 2011: 1042)
"魚通常在盤旋時表現出向內的反向傳播波（兩個獨立的波從身體的兩端傳播，在中間相遇） - 保持靜止並主動穩定以對抗擾動。"（Curet 等人，2011：1042）

參考文獻清單與連結 (REFERENCE LIST) **Harvard 或 APA 格式**

Aquatic manoeuvering with counter-propagating waves: a novel locomotive strategy

Journal of The Royal Society Interface | 23/12/2010 | O. M. Curet, N. A. Patankar, G. V. Lauder, M. A. MacIver
https://royalsocietypublishing.org/doi/10.1098/rsif.2010.0493

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