

## Why can they fly and swim? Dynamic similarity between flight and swimming in Rhinoceros auklets

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For seabirds, long span wings are efficient for flight, though short span wings are efficient for swimming, because of the drastic difference of air and sea water density. In spite of this morphological trade-off, alcids are compatible with wing-propelled aerial flight and aquatic swim. How do alcids fly and swim? In many flying or swimming animals, the strouhal number( $St$ ), which is the indicator of propulsive efficiency, are known to tune as efficient value( $0.2 < St < 0.4$ ) during cruising.  $St$  is defined as  $St = \text{wingbeat Frequency} * \text{wing stroke amplitude} / \text{forward speed}$ . Thus, we hypothesize that alcids might adjust the wing kinematics and tune  $St$  as  $0.2 - 0.4$  during flight and swimming. We measured wingbeat frequency, wing stroke amplitude and forward speed using micro data loggers and video movies on Rhinoceros auklets *Cerorhinca monocerata* at Teuri Island, Japan. Rhinoceros auklets fly at  $15.66 \pm 0.9\text{m/sec}$  and flap at high frequency( $8.81 \pm 0.3\text{Hz}$ ) with large amplitude( $0.32\text{m}$ ). In contrast, they swim at  $1.28 \pm 0.1\text{m/sec}$  and flap at low frequency( $2.61 \pm 0.4\text{Hz}$ ) with small amplitude( $0.14\text{m}$ ).  $St$  is calculated as  $0.18$  during flight and  $0.27$  during swim. Therefore, Rhinoceros auklets change their wing movement and tune the  $St$  as efficient value during flight and swimming.