

(続紙 1)

京都大学	博士（農学）	氏名	BHANDARE CHAITANYA KUMAR
論文題目	Growth and survival of Japanese flounder <i>Paralichthys olivaceus</i> juveniles in Tango Bay, Sea of Japan: Implications for population dynamics under climate change (丹後海のヒラメ稚魚の成長と生残：気候変動下における個体群動態の予察)		
(論文内容の要旨)			
Chapter 1 of the thesis presents the general introduction, outlining the background and purpose of the research. Early life stages of marine fish are highly sensitive to environmental fluctuations, particularly changes in water temperature and prey availability, both increasingly influenced by climate change. The Japanese flounder (<i>Paralichthys olivaceus</i>), an ecologically and commercially important flatfish, may face major challenges during the juvenile stage that affect feeding, growth, survival, morphological development, and genetic traits. Tango Bay in the Sea of Japan, a well-documented nursery ground for this species, offers an ideal setting to examine how climate-driven environmental changes impact early life history traits and population dynamics. Accordingly, this chapter establishes the context and rationale for investigating how ecological factors may influence juvenile growth, survival, recruitment potential, and population structure, with particular attention to cohort-specific growth patterns, dietary shifts, and genotypic sex ratios. In Chapter 2, the cohort-specific growth, survival, and recruitment potential of Japanese flounder juveniles are examined. Japanese flounder juveniles were collected weekly covering the settlement period (April to June) in 2007 and 2008. Hatch dates were estimated using otolith microstructure analysis, enabling the juveniles to be grouped into biweekly cohorts for subsequent analysis. Cohort-specific growth rates of Japanese flounder juveniles increased as the season progressed. The early cohorts experienced cooler temperatures but benefited from high availability of mysids, while the late cohorts maintained relatively high growth despite declining mysid abundance, suggesting alternate food sources. The mid-season cohorts exhibited the highest mortality rates in both years, coinciding with peak abundance and indicating density-dependent mortality. The mid-season cohorts also showed strong growth-selective mortality during the early post-settlement stage. High densities of Japanese flounder juveniles likely suffered from food limitation incidental to a seasonal decline in mysid density. This may cause mass mortality in smaller individuals due to predation including cannibalism. Recruitment potential, evaluated through M/G (mortality/growth) ratios, was lowest in the mid-season cohorts due to elevated mortality despite high initial densities. In contrast, the early and late cohorts showed higher recruitment potential, supported either by favorable prey conditions or reduced competition. In combination, the			

findings underscore that cohort-specific growth, mortality, and recruitment potential in juvenile Japanese flounder were shaped by the interactive effects of temperature, food availability, and population density in Tango Bay.

In Chapter 3, ontogenetic and seasonal dietary shifts are examined to understand their role in the density-dependent and growth-selective mortality patterns identified in Chapter 2. Stomach content analysis across cohorts and size classes in 2008 was used to assess how these dietary shifts influenced growth and survival, revealing that mysids, mainly *Orientomysis japonica*, were the primary prey throughout early development. The early cohorts benefited from high mysid availability, while the mid- and late cohorts relied on mysids despite seasonal decline; larger juveniles increasingly consumed prey fish, with amphipods contributing modestly in late cohorts, likely as an alternative food when mysid availability was reduced. Feeding habits also varied by body size, with smaller juveniles consuming smaller, uniform prey, and larger juveniles consuming a wider prey size range, reflecting enhanced predatory ability and prey scarcity. Stomach Content Index (SCI) values were lowest in the smallest and largest size classes, indicating potential food limitation in both groups. The mid-season cohort had the highest frequency of empty stomachs among newly settled juveniles, likely due to competition at peak settlement. Juveniles with prey items grew significantly faster than those with empty stomachs, reinforcing the link between feeding success and growth-dependent survival. As hypothesized in Chapter 2, early cohorts preyed on newly settled conspecifics from the mid-season cohort, contributing to high mortality via cannibalism. Collectively, these findings indicate that ontogenetic feeding shifts, prey availability, and interactions between cohorts, including cannibalism, played key roles in shaping growth, survival, and recruitment potential in Japanese flounder juveniles.

Chapter 4 investigated genotypic sex ratios in Japanese flounder juveniles from Tango Bay across seasonal cohorts in 2007 and 2008. Genotypic sex (male: XY; female: XX) was determined using molecular markers, revealing a consistent female-biased ratio that increased from the early to late cohorts. These deviations from the expected 1:1 ratio are unlikely to result from natural variation alone and may reflect environmental factors such as thermal conditions during early development. In Japanese flounder, genotypic females (XX) can undergo masculinization under stressors such as elevated temperatures and high densities, producing phenotypic males that retain the XX genotype. Another possible cause is large-scale releases of thermally masculinized XX males from hatcheries along the Sea of Japan coast. These males, producing only X-bearing sperm, could gradually shift the genotypic sex composition in wild populations toward an excess of XX offspring. No significant differences in growth rates were found between genotypic

males and females during the first month post-settlement, suggesting minimal sexual dimorphism at this stage. Similarly, dorsal fin ray (DFR) counts did not differ between genotypic sexes, but a seasonal decline was observed, with higher counts in the early cohorts and lower counts in the late ones. This trend may reflect the sequential arrival of genetically distinct populations—southern-origin cohorts settling earlier with higher DFR counts, followed by northern-origin cohorts with lower counts. Overall, these findings highlight the combined effects of temperature exposure, geographic origin, and hatchery influence in shaping genotypic traits. Understanding these interactions is essential for evaluating the reproductive potential, stock composition, and long-term viability of Japanese flounder populations under ongoing climate change.

In Chapter 5, regional differences in Japanese flounder population dynamics under climate change are discussed. Previous studies show that regional environmental differences produce varied outcomes. Cooler, stable conditions and prolonged prey availability in northern areas can support higher juvenile growth and survival, while earlier warming, variable prey, and stronger density-dependent mortality in southern areas like Tango Bay increase recruitment uncertainty. The Seto Inland Sea shows further regional vulnerability, where recent warming and prey shifts have contributed to declining productivity and reduced survival of mass-released juveniles. Regional variation in predator pressure may also play a role, with evidence of stronger predation on juveniles in southern regions compared to the north. These findings suggest that climate change may have contrasting effects across regions, potentially enhancing recruitment in northern populations while increasing ecological stress in southern populations like Tango Bay.

In summary, this study shows that climate-driven warming affects the early life history of Japanese flounder by influencing growth, mortality, feeding ecology, and genotypic sex composition. Patterns of density- and growth-dependent mortality, female-biased sex ratios, and seasonal changes in meristic traits indicate that temperature and genetic background are key drivers of juvenile characteristics. The results underscore how density, prey availability, and genotypic shifts interact with climate-related stressors to shape recruitment and population structure.

注) 論文内容の要旨と論文審査の結果の要旨は1頁を38字×36行で作成し、合わせて、3,000字を標準とすること。

論文内容の要旨を英語で記入する場合は、400～1,100 wordsで作成し
審査結果の要旨は日本語500～2,000字程度で作成すること。

(続紙 2)

(論文審査の結果の要旨)

ヒラメは水産資源としての重要性が高いことから、初期生活史に関する知見は豊富であり、またその増養殖についての研究も盛んである。一方、本種が沖合産卵場から沿岸生育場に加わった直後の成長と生残について、加入時期を通して環境との関係の詳細に調べた研究はこれまでなかった。本研究は、日本海に位置する丹後海において高頻度でヒラメ稚魚の採集を実施し、その成長・生残・摂餌状況および遺伝的な性比等を詳細に分析している。評価すべき点は以下の通りである。

1. ヒラメの加入時期である4月から6月にかけて、毎週の曳網調査を2カ年にわたり行なってヒラメ稚魚を採集し、耳石の輪紋数から孵化日を推定するとともに輪紋幅から成長履歴を明らかにした。加入を前中後期に分けると、前期群は豊富な餌を得て、また後期群は高い水温により高成長を示すこと、中期群は生息密度の上昇にともなう餌獲得競争の激化により生残率が低いことを見出した。

2. ヒラメ稚魚は加入直後の餌料としてアミ類に強く依存しており、以後成長に伴い大型の餌生物である魚類への依存を高めること、アミ類の減少する加入後期にはアミ類より小型の餌生物であるヨコエビ類を補助的に利用することを示した。

3. ヒラメ稚魚の遺伝的な性比は、加入の後期において雌 (XX) に偏ることを見出した。ヒラメ稚魚では遺伝的雌個体が高水温ストレスにより機能的に雄化することが知られていることから、このような雄化個体が成熟して繁殖に加わることで個体群内で遺伝的雌個体の割合が上昇した可能性を指摘した。この要因として、天然海域の温暖化ばかりでなく放流種苗育成時の加温の影響も考えられた。

以上のように本論文は、ヒラメ稚魚の生活史についての理解を深め、温暖化の進行する沿岸域での本種資源の管理に大きく貢献するものであり、水産学、沿岸海洋学、水産資源学の発展に寄与するところが大きい。よって、本論文は博士 (農学) の学位論文として価値あるものと認める。

なお、令和7年7月17日、論文並びにそれに関連した分野にわたり試問した結果、博士 (農学) の学位を授与される学力が十分あるものと認めた。

また、本論文は、京都大学学位規程第14条第2項に該当するものと判断し、公表に際しては、当該論文の全文に代えてその内容を要約したものとすることを認める。

注) 論文内容の要旨、審査の結果の要旨及び学位論文は、本学学術情報リポジトリに掲載し、公表とする。

ただし、特許申請、雑誌掲載等の関係により、要旨を学位授与後即日公表することに支障がある場合は、以下に公表可能とする日付を記入すること。

要旨公開可能日： 年 月 日以降 (学位授与日から3ヶ月以内)