

## Background

This information is intended to provide you with a basic overview of *Elodea*'s habitat suitability, long-distance dispersal, and ecological impact. Below, we also describe the task and define the habitat characteristics. This information is by no means complete in describing the complexity and potential alterations of ecosystem processes affected by *Elodea*. Instead, we aim at a broad overview of ecological effects that could be related to the viability of salmonid populations in Alaska. We also realize that scientific evidence from outside Alaska limits transferability to Alaska locations and environmental conditions. However, we believe that in data limited situations such as this, non-site-specific literature is essential in establishing a baseline from which to start the discussion.

### *Elodea* Habitat Suitability & Dispersal

- Tolerant of a wide range of freshwater quality conditions.
- Has invaded aquatic ecosystems worldwide.
- Prefers sand and small gravel substrate with large amounts of available iron in cold, static or slow-moving water (up to a velocity between 0.3 and 0.4 m/s).<sup>1</sup>
- Grows in lakes between 0.2 and 2 m depth with maximum extent to 9 m in depth, but is generally absent from frequently draining/drying and very shallow waters.<sup>2, 3</sup>
- In slow moving streams and rivers grows in depths between 0 and 0.9 m potentially deeper depending on turbidity.<sup>1</sup>
- Prefers habitat with flood frequencies of less than 13 per year (ideally less than 8), where flood is defined as seven times the median discharge. Preferred substrate is sand and small gravel. The species requires light and does not prefer turbid water.<sup>1</sup>
- Since *Elodea* is known to be a nutrient scavenger, eutrophic waters are more supportive of heavy long-term infestations.<sup>3,2</sup>
- The life span of *Elodea* shoots is 1-2 years and especially in oligotrophic conditions, *Elodea* may not persist long term.
- Stem fragments and vegetative buds easily break away from the parent plants and float to new locations, where they root at the nodes.
- Stem fragments have higher survival rates in fall than in spring.<sup>4</sup>
- Vegetative buds can survive desiccation, low temperatures, and can survive frozen in ice.<sup>5,6</sup>
- Flooding can significantly increase density of propagules.
- Stem fragments are dispersed by waterfowl, wildlife, humans, boat props or trailers, and float plane rudders.

## Habitat Characteristics

1. **Dense aquatic vegetation cover:** *Elodea* outcompetes native plants and reduces the amount of light available to surrounding vegetation, thereby eliminating underlying layers.<sup>3,6</sup> In Chena Slough near Fairbanks, Alaska, this species has formed dense monocultures, creating a new layer of tall aquatic vegetation, reaching 100% mean cover in some areas. *Elodea* can form dense mats, especially on iron-rich substrates<sup>6</sup>, displacing native plant species, decreasing planktonic productivity, and reducing local biodiversity.<sup>3,8</sup> In contrast, observed conditions for uninvaded lakes in Alaska suggest much less vegetation to be the norm. For 50 randomly selected un-invaded lakes in Cook Inlet, the aquatic vegetation mean % cover for uninvaded lakes is 27%, median 22%, mode 8%, minimum 0%, and maximum 78%.<sup>29</sup>

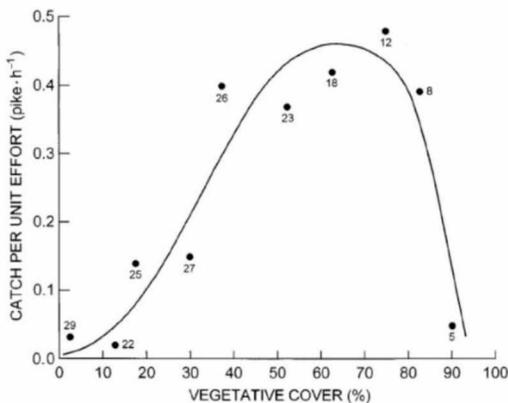
2. **Lower dissolved oxygen above substrate and altered conditions throughout the water column:** In water of 5 mg/l dissolved oxygen (DO), *Elodea* was documented to have increased DO in the upper parts of the plants to 9 mg/l but reduced DO concentrations within 5 cm of the substrate to 0.4 mg/l.<sup>6</sup> During the night, productive macrophyte beds can also deplete the water column of DO through respiratory activities, thereby promoting phosphorus release from sediments under anoxic conditions.<sup>7</sup> Frequent die-back events can lead to perturbation of the entire lake ecosystem with very low DO concentrations during die-back.<sup>7, 15-17</sup> For 50 randomly selected un-invaded lakes in Cook Inlet, the mean DO level at 1 m depth for uninvaded lakes measured in September was 7 mg/l, median 6.79 mg/l, minimum 5.07 mg/l, and maximum 11.03 mg/l. The mean water temperature at 1 m depth was 14.46 °C.<sup>29</sup>

3. **Increased but variable prey abundance with potentially inferior food quality:** Phenotypic plasticity has been identified as an important trait largely responsible for enabling invaders to produce negative effects on aquatic food webs.<sup>27</sup> *Elodea canadensis* supports low densities of epiphytic organisms (organisms that grow on plant surfaces non-parasitically), possibly because this species exudes allelopathic chemicals. Extracts from *Elodea canadensis* have been shown to reduce the growth of epiphytic algae, cyanobacteria, and lepidopteron larvae with potential food web effects reducing resources available to phytoplankton and other submerged aquatic vegetation. Some studies indicate that allelopathic chemicals can affect fish through direct effects of toxicity and a potential reduction in food items by reducing the abundance and survival of macroinvertebrates that feed on *Elodea spp.*<sup>26</sup> However, it is unknown if plants exude the allelopathic chemicals at ecologically significant concentrations. Potential allelopathic effects of *Elodea canadensis* on other aquatic plants have not been observed.<sup>10</sup>

Aquatic vegetation may affect the densities of fishes (salmonids) and their prey resources (zooplankton / macroinvertebrates) mostly through its positive effect on the productivity of the prey's resources. The degree to which submerged aquatic plants encourage the growth and assemblage of food sources for fish is complex. Submerged macrophytes act as refuge for zooplankton against fish predation if plant cover is larger than 15 to 20%, but this refuge effect almost disappears if fish density exceeds a threshold of 4 fish/m<sup>2</sup>.<sup>15</sup> For oligotrophic lakes this refuge effect will often be low due to low plant height.<sup>15</sup> Besides plant height, a more dense structure can have positive refuge effects as well. For 50 randomly selected un-invaded lakes in Cook Inlet, the mean macroinvertebrate abundance count was 548 /m<sup>2</sup>, minimum 374/m<sup>2</sup>, and maximum 1125/m<sup>2</sup>. Zooplankton biomass in Alaska nursery lakes measured in mg dry weight /m<sup>2</sup> ranges from a low of 22 mg/m<sup>2</sup> to a high of 2223 mg/m<sup>2</sup> with a mean of

515 mg/m<sup>2</sup>.<sup>23</sup> The *levels* for invaded habitat were chosen to reflect the large variance suggested by the literature.

4. **Increased predation:** *Elodea* beds are preferred habitat for northern pike (*Esox lucius*) spawning and feeding. Predation effects depend on how dense the *Elodea* beds are.<sup>11,12</sup> Adult pike abundance is related to the extent of aquatic plant cover, which is optimal from 35% to 80% but inversely related to body size. Very dense vegetative cover appears to be suboptimal, especially for larger northern pike. Research conducted in the tributaries of the Susitna River, Alaska, indicate that juvenile salmonids are the dominant prey item with small pike being the primary consumers. The introduction of pike into these systems can have varying effects on salmonids that highly depend on whether habitats overlap in which case collapse of salmonid populations is possible.<sup>13,14</sup> Casselman and Lewis (1996) illustrate the relationship between pike abundance and aquatic vegetation cover as follows:



A recent study of invasive pike predation in Upper Cook Inlet revealed pike densities of 15 pike/acre. Pike densities in other areas of Alaska where pike is native are generally lower at around 5 pike/acre.<sup>14</sup> Due to the likely increased density of vegetation cover in invaded salmon habitat we assume increased spawning habitat for pike and increased predator efficiency and productivity.

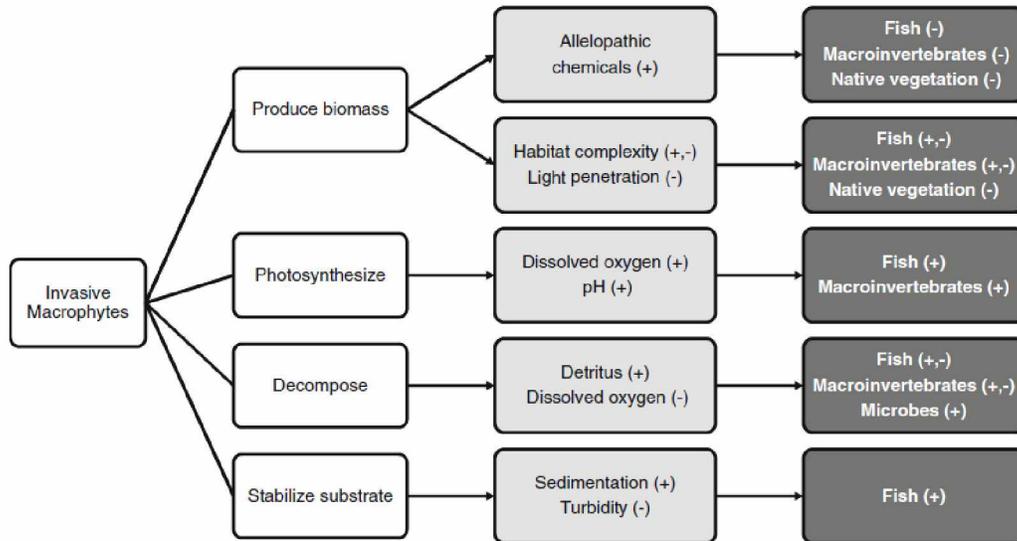
5. **Uncertain invasion dynamics:** Planctonic primary production can increase after invasion of an aquatic plant and decline to pre-invasion levels during extensive plant die back incidents (boom-bust-cycles), causing significant perturbations of the whole-lake ecosystem.<sup>7, 15-17</sup> Spontaneous collapses of *Elodea* infestations have been observed across Europe and Japan. While the rise and fall pattern is common, the cause of die backs are often unknown. Contrary, a mass invasion of *Elodea* has been extensively studied in Norway's Lake Steinsfjord where it first appeared in 1978. Peak biomass was observed within six years after invasion and has been stable since then, reaching up to 1.2 kg of dry weight/m<sup>2</sup>.<sup>2</sup>

6. **Strong thermal gradients:** both vertically and laterally, in shallow littoral zones. Foliage near the surface converts solar irradiance to heat, further promoting differential heating.<sup>7</sup>

7. **Increased sediment loading & reduced water exchange:** submersed aquatic plant populations can restrict water flow and lead to sediment loading in areas of dense vegetation, but they can also stabilize the substrate.

8. **Increased pH, variable phosphorus:** Infestations increase the turbidity and pH of water and cause significant variations in phosphorus concentrations. *Elodea* accumulates nutrients while reducing nutrient availability in the substrate. However, populations are likely to decline as iron is removed from the substrate.<sup>6</sup>

Schultz and Dibble (2012) summarize the potential ecosystem impacts of invasive aquatic plants in the conceptual model below.



**Fig. 1** Effects of invasive macrophytes on the ecosystem. Plant functions (white) and associated effects on abiotic (light gray) and biotic (dark gray) factors are shown. The plus (+) and minus (-) signs indicate the positive or negative response of the

variable to an increase in the invasive macrophyte, respectively. In certain cases, the biotic response is unimodal instead of linear (as in the response of fish to habitat complexity), therefore both signs are used to depict the relationship

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